VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLX.—APRIL, 1882.—VOL. XXVI.

ON THE MECHANICAL PRODUCTION OF ELECTRIC CURRENTS.

From "Engineering."

THE object of these articles is to lay down in the simplest and most intelligible way the principles which are concerned in the mechanical production of electric currents. Every one knows now that electric lights are produced from powerful currents of electricity generated in a machine containing magnets and coils of wire, and driven by a steam engine, or gas engine, or water wheel. But of the thousands who have heard that a steam engine can thus provide us with electric currents, how many are there who comprehend the action of the generator or dynamo-electric machine? How many, of engineers even, can explain where the electricity comes from, or how the mechanical power is converted into electrical energy, or what the magnetism of the iron magnets has to do with it all? Take any one of the dynamo-electric machines of the present date—the Siemens, the Gramme, the Brush, or the Edison machine—of each of these there exist descriptions excellent in their way, and sufficient for men already versed in the technicalities of electric science. But to those who have not served an apprenticeship to the technicalities—to all but professed electricians—the action of these machines is almost an unknown mystery. As, however, an understanding of the how and the why of the dynamo-electric machine or generator is the very A B C of electrical engineering, an exposition of the fundamental principles of the mechanical production of electric currents demands an important place in the current science of the day. It will be our endeavor to expound these principles in the plainest terms, while at the same time sacrificing nothing in point of scientific accuracy or of essential detail.

The modern dynamo-electric machine or generator may be regarded as a combination of iron bars and copper wires, certain parts of the machinery being fixed, whilst other parts are driven round by the application of mechanical force. How the movement of copper wires and iron bars in this peculiar arrangement can generate electric currents is the point which we are proposing to make clear. Friction has nothing to do with the matter. The old-fashioned spark-producing "electrical machine" of our youthful days, in which a glass cylinder or disc was rotated by a handle whilst a rubber of silk pressed against it, has nothing in common with the dynamo-electric generator, except that in both something turns upon an axis as a grindstone, or the barrel of a barrel-organ may do. In the modern "dynamo" we cannot help having friction at the bearings and contact pieces, it is true, but there should

be no other friction. The moving coils of wire or "armatures" should rotate freely without touching the iron pole pieces of the fixed portion of the machine. In fact friction would be fatal to the action of the "dynamo." How then does it act? We will proceed to explain without further delay. There are, however, three fundamental principles to be borne in mind if we would follow the explanation clearly from step to step, and these three principles must be laid down at the very outset.

1. The first principle is that the existence of the energy of electric currents, and also the energy of magnetic attractions, must be sought for not so much *in the wire* that carries the current, or *in the bar* of steel or iron that we call a magnet, as *in the space that surrounds* the wire or the bar.

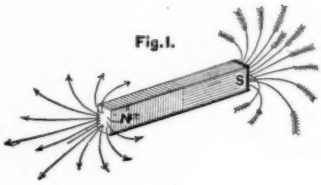
2. The second fundamental principle is that the electric current is, in one sense, quite as much a *magnetic* fact as an electrical fact; and that the wire which carries a current through it has magnetic properties (so long as the current flows) and can attract bits of iron to itself as a steel magnet does.

3. The third principle to be borne in mind is that to do work of any kind, whether mechanical or electrical, requires the expenditure of energy to a certain amount. The steam engine cannot work without its coal, nor the laborer without his food; nor will a flame go on burning without its fuel of some kind or other. Neither can an electric current go on flowing, nor an electric light keep on shedding forth its beams, without a constant supply of energy from some source or other.

The last of these three principles, involving the production of electric currents for the work they are to do and to the energy expended in their production, will be treated of separately and later. Meantime we resume the task of showing how such currents can be produced mechanically, and how magnetism comes in in the process.

Surrounding every magnet there is a "field" or region in which the magnetic forces act. Any small magnet, such for example as a compass needle, when brought into this field of force, exhibits a tendency to set itself in a certain direction. It turns so as to point with its north pole toward the south pole of the magnet, and with its south pole toward the north pole of the magnet; or if it cannot do both these things at once, it takes up an intermediate position under the joint action of the separate forces and sets in along a certain line. Such lines of force run through the magnetic "field" from one pole of the magnet to the other in curves. If we define a line of force as being the line along which a free north-seeking magnetic pole would be urged, then these lines will run from the north pole of the magnet round to the south pole, and pass through the substance of the magnet itself. In Fig. 1

Fig. 1.



a rough sketch is given of the lines of magnetic force as they emerge from the poles of a bar magnet in tufts. The arrow heads show the direction in which a free north pole would move. These lines of force are no fiction of the imagination like the lines of latitude and longitude on the globe; they exist and can be rendered visible by the simplest expedients. When iron filings are sprinkled upon a card or a sheet of glass, below which a magnet is placed, the filings set themselves—especially if aided by a gentle tap—along the lines of force. Fig. 2 is a reproduction from nature of this very experiment, and surpasses any attempt to draw the lines of force artificially. It is impossible to magnetize a magnet without also in this fashion magnetizing the space surrounding the magnet; and the space thus filled with the lines of force possesses properties which ordinary unmagnetic space does not possess. These lines give us definite information about the magnetic condition of the space where they are. Their direction shows us the direction of the magnetic forces, and their density shows us the strength of the magnetic forces; for where the force is strongest there we have the lines of force most

numerous and most strongly delineated in the scattered filings. To complete this first consideration of the magnetic

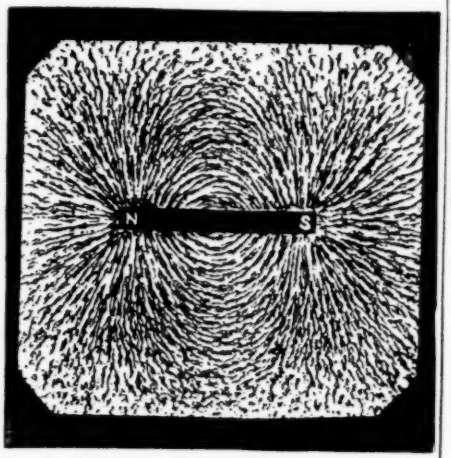


Fig. 2.

field surrounding a magnet, we will take a look at Fig. 3, which reproduces the lines of filings as they settle in the field

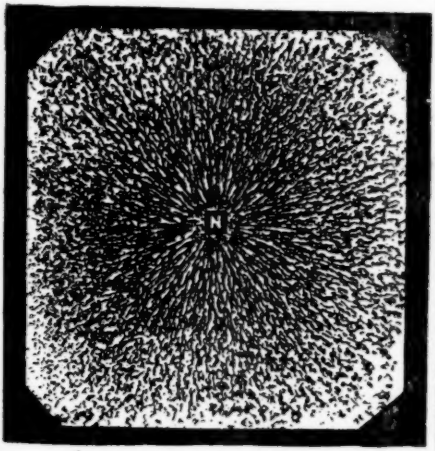
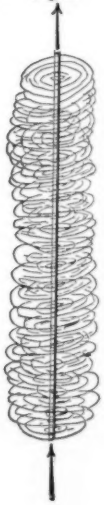


Fig. 3.

of force opposite the end of a bar magnet. The repulsion of the north pole of the magnet upon the north poles of other magnets would be, of course, in lines diverging radially from the magnet pole.

We will next consider the space surrounding a wire through which a current of electricity is flowing. This wire has magnetic properties so long as the current continues, and will, like a magnet, act on a compass needle. But the needle never tries to point toward the wire, its tendency is always to set itself broadside to the current and at right angles to it. The "field" of a current flowing up a straight wire is, in fact, not unlike the sketch shown in Fig. 4, where instead of

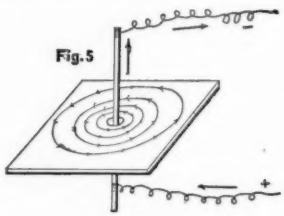
Fig. 4.



tufted groups we have a sort of magnetic whirl to represent the lines of force. The lines of force of the galvanic field are, indeed, circles or curves which enclose the conducting wire, and their number is proportional to the strengh of the current. In the figure, where the current is supposed to be flowing up the wire (shown by the dark arrows), the little arrows show the direction in which a free north pole would be urged round the wire; * a south pole would, of course, be urged round the wire in the

* It will not be out of place here to recall Ampere's ingenious rule for remembering the direction in which a current urges the pole of a magnetic needle. "Suppose a man swimming in the wire with the current, and that he turns so as to face the needle, then the north pole of the needle will be deflected towards his left hand."

contrary direction. Now, though when we look at the telegraph wires, or at any wire carrying a current of electricity, we cannot *see* these whirls of magnetic force in the surrounding space there is no doubt that they exist there, and that a great part of the energy spent in starting an electric current is spent in producing these magnetic whirls in the surrounding space. There is, however, one way of showing the existence of these



lines of force; similar, indeed, to that adopted for showing the lines of force in the field surrounding a magnet. Pass the conducting wire up through a hole in a card or a plate of glass, as shown in Fig. 5, and sprinkle filings over the surface. They will, when the glass is gently tapped, arrange themselves in concentric

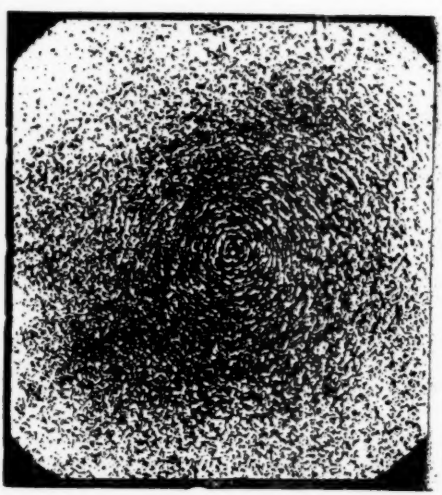


Fig. 6.

circles, the smallest and innermost being the best defined because the magnetic force is strongest there. Fig. 6 is an actual reproduction of the circular lines produced in this fashion by iron filings in the field of force surrounding an electric current.

This experimental evidence must suffice to establish two of the three fundamental points stated at the outset, for they prove conclusively that the electric current may be treated as a magnetic phenomenon, and that both in the case of the pole of a magnet, and in that of the wire which carries a current, a portion, at any rate, of the energy of the magnetic forces exists outside the magnet or the current, and must be sought in the surrounding space.

Having grasped these two points, the next step in our argument is to establish the relation between the current and the magnet, and to show how one may produce the other.

If we wind a piece of copper wire into a helix or spiral, as in Fig. 7, and pass a

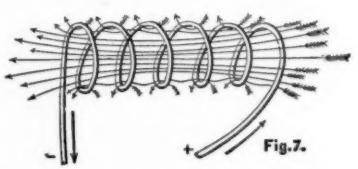


Fig.7.

current of electricity through it, the magnetic whirls in the surrounding space are modified, and the lines of force are no longer small circles wrapping round the conducting wire. For now the lines of force of adjacent strands of the coil merge into one another, and run continuously through the helix from one end to the other. Compare this figure with Fig. 1, and the similarity in the arrangement of the lines of force is obvious. The front end of the helix acts, in fact, like the north pole of a magnet, and the further end like the south pole. If a small bar of iron be now pushed into the interior of this helix, the lines of force will run through it and magnetize it, converting it into an *electro magnet*. The magnetic "field" of such an electro magnet is shown in Fig. 8, which is reproduced from the actual figure made by iron filings. To magnetize the iron bar of the electro magnet as strongly as possible the wire should be coiled many times round, and the current should be as

strong as possible. This mode of making an iron rod or bar into a powerful magnet is adopted in every dynamo-electric machine. For, as will be presently explained, very powerful magnets are required, and these magnets are most effectively made by sending the electric currents through spiral coils of wirt wound (as in Fig. 8) round the bars thae are to be made into magnets.

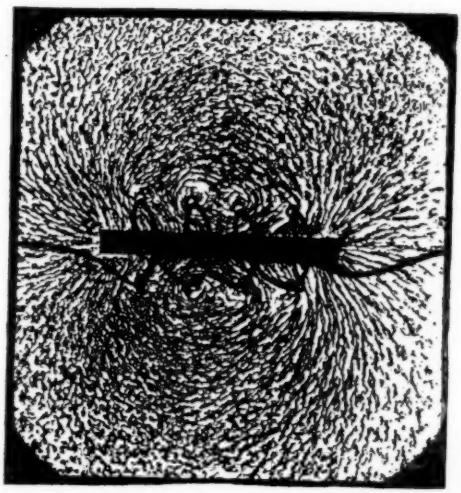


Fig. 8.

The reader will at this point probably be ready to jump to the conclusion that magnets and currents are alike surrounded by a sort of magnetic atmosphere, and such a view may help those to whom the subject is fresh to realize how such actions as we have been describing can be communicated from one magnet to another, or from a current to a magnet. Nevertheless, such a conclusion would be both premature and inaccurate. Even in the most perfect vacuum these actions still go on, and the lines of force can still be traced. It is probably more correct to conclude that these magnetic actions are propagated through space not by special magnetic atmospheres, but by there being movements and pressures and tensions in the *æther* which is believed to pervade all space as a very thin medium more attenuated than the lightest gas, and which when subjected to electro magnetic forces assumes a peculiar state, and gives rise to the actions which have been detailed in the preceding paragraph.

In the first article on this subject, we described how the electric current, or rather the wire through which it flows, possesses for the time magnetic properties, and is surrounded by lines of force. It was further shown how magnetism can be produced from electric currents, a spiral coil of wire through which a current is sent acting like a magnet.

The next point to be studied is the magnetic property of a single loop of the wire through which an electric current flows. Fig. 9 represents a single voltaic cell containing the usual plates of zinc and copper dipping into acid to generate a current in the old-fashioned way. This current flows from the zinc plate through the liquid to the copper plate, and from thence it flows round the wire ring or circuit back to the zinc plate. Here the lines of magnetic force in the surrounding space are no longer only whirls like those drawn in Figs. 4 and 6, for they react on one another and become nearly parallel where they pass through the middle of the ring. The thick arrows show the direction of the electric current, the fine arrows are the lines of magnetic force, and show the paths along which a

free north pole would be urged. All the front face, where the arrow-heads are, will be like the north pole of a magnet. All the other face of the ring will be like the south pole of a magnet. Our ring resembles a flat magnet, one face all north pole the other face all south pole. Such a magnet is sometimes called a "magnetic shell."*

termed "Maxwell's Rule," is very important, because it can be so readily applied to so many cases, and will enable one so easily to think out the actual reaction in any particular case. The rule is illustrated by the sketch shown in Fig. 10, where a bar magnet has been placed with its north pole opposite the south face of the circuit of the cell. The lines of

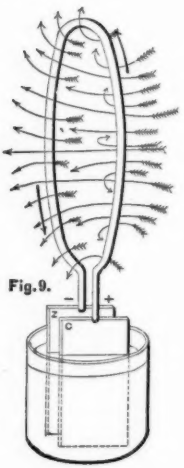


Fig. 9.

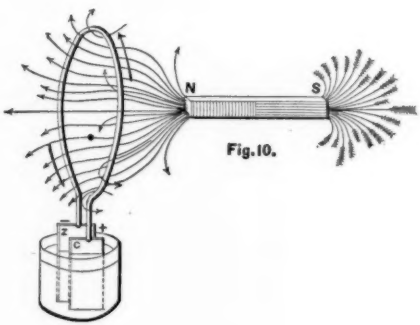


Fig. 10.

Since the circuit through which the current is flowing has these magnetic properties, it can attract other magnets or repel them according to circumstances.

If a magnet be placed near the circuit, so that its north pole N is opposite that side of the circuit which acts as a south pole, the magnet and the circuit will attract one another. The lines of force that radiate from the end of the magnet, curve round and coalesce with some of those of the circuit. It was shown by the late Professor Clerk-Maxwell that every portion of a circuit is acted upon by a force urging it in such a direction as to make it enclose within its embrace the greatest possible number of lines of force. This proposition, which has been

force of the magnet are drawn into the ring and coalesce with those due to the current. According to Faraday's mode of regarding the actions in the magnetic field, there is a tendency for the lines of force to shorten themselves. This would occur if either the magnet were pulled into the circuit, or the circuit were moved up towards the magnet. Each attracts the other, and whichever of them is free to move will move in obedience to the attraction. And the motion will in either case be such as to increase the total number of lines of force that pass through the circuit. Lest it should be thought that Fig. 10 is fanciful or overdrawn, we reproduce an actual magnetic "field" made in the manner described in the preceding article. Fig. 11 is a kind of sectional view of Fig. 10, the circuit being represented merely by two circular spots or holes above and below the middle line, the current flowing towards the spectator through the lower spot, and passing in front of the figure to the upper hole where it flows down. Into this

* The rule for telling which face of the magnetic shell (or of the loop circuit) is north and which south in its magnetic properties is the following. If as you look at the circuit the current is flowing in the same apparent direction as the hands of a clock move, then the face you are looking at is a south pole. If the current flows the opposite way round to the hands of a clock then it is the north pole face that you are looking at.

circuit the pole N is attracted, the tendency being to draw as many lines of force as possible into the embrace of the circuit.

So far as the reasoning about these mutual actions of magnets and currents is concerned, it would therefore appear that the lines of force are the really important feature to be understood and studied. All our reasons about the attractions of magnets could be equally well thought of if there were no corporeal magnets there at all, only collections of lines of force. Bars of iron and steel may be regarded as convenient conductors of the lines of force; and the poles of magnets are simply the places where the lines of force run out of the metal into the air, or *vice versa*. Electric currents also may be reasoned about, and their magnetic actions foretold quite irrespective of the copper wire that acts as a conductor: for here there are not even any poles; the lines of force or magnetic whirls are entirely outside the metal. There is an important difference, however, to be observed between the case of the lines of force of the current, and that of the lines of force of the magnet. The lines of force of the magnet *are* the magnet so far as magnetic forces are concerned; for a piece of soft iron laid along the lines of force thereby becomes a magnet and remains a magnet as long as the lines of force pass through it. But the lines of force crossing through a circuit are not the same thing as the current of electricity that flows round the circuit. You may take a loop of wire and put the poles of magnets on each side of it so that the lines of force pass through in great numbers from one face to the other, but if you have them there even for months and years the mere presence of these lines of force will not create an electric current even of the feeblest kind. There must be *motion* to induce a current of electricity to flow in a wire circuit.

Faraday's great discovery was, in fact, that when the poles of a magnet is moved into, or moved out of, a coil of wire, the motion produces, while it lasts, currents of electricity in the coil. Such currents are known as "induced currents"; and the action is called magneto-electric "induction." The momentary current produced by plunging the magnet pole into the wire coil or circuit is found to be in the opposite direction to that in which a current must be sent, if it were desired to attract the magnet pole into the coil. If the reader will look back to Fig. 10 he will see that a north magnet pole is being attracted in from behind into a circuit round which, as he views it, the current flows in an opposite sense to that in which the hands of a clock move round. Now, compare this figure with Fig. 12, which represents the generation of a mo-

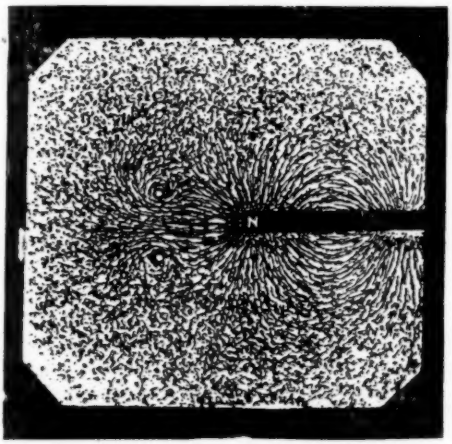


Fig. 11.

mentary induced current by the act of moving the north pole N towards a wire ring, which is in this case connected with a little detector galvanometer G. The momentary current flows round the circuit (as seen by the spectator from the

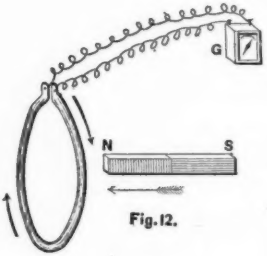


Fig. 12.

front) in the *same* sense as the movements of the hands of a clock. The induced current which results from the motion is found, then, to be in a direction exactly opposed to that of the current that would itself produce the same movement of the magnet pole. If the north pole instead of being moved towards or into the circuit were moved away from the circuit, this motion will also induce a transient current to flow round the wire, but this time the current will be in the same sense as that in Fig. 10, in the opposite sense to that in Fig. 12. Pulling the maget pole away sets up a current in the reverse direction to that set up by pushing the pole nearer. In both cases the currents only last while the motion lasts.

Now in the first article it was pointed out that the lines of force of the magnet indicate not only the direction, but the strength of the magnetic forces. The stronger the pole of the magnet is, the greater will be the *number of lines of force* that radiate from its poles. The strength of the current that flows round a circuit is also proportional to the number of lines of force which are thereby caused to pass (as in Fig. 9) through the circuit. The stronger the current, the more numerous the lines of force that thread themselves through the circuit. When a magnet is moved near a circuit near it, it is found that any alteration in the number of lines of force that cross the circuit is accompanied by the production of a current. Referring once more to Fig. 10, we will call the direction of the current round the circuit in that figure the *positive* direction; and to define this direction we may remark that if we were to view the circuit from such a point as to look along the lines of force in their own direction the direction of the current round the circuit will appear to be the same as that of the hands of a clock moving round a dial. If the magnet N S be now drawn away from the circuit so that fewer of its lines of force passed through the circuit, experiment shows the result that the current flowing in circuit will be for the moment increased in strength, the *increase* in strength being proportional to the rate of *decrease* in the number of lines of force. So, on the other hand, if the magnet were pushed up toward the circuit, the current in the circuit would be momentarily reduced in strength, the decrease in strength in the current being proportional to the rate of increase in the number of lines of force.

Similar considerations apply to the case of the simple circuit and the magnet shown in Fig. 12. In this circuit there is no current flowing so long as the magnet is at rest; but if the magnet be moved up toward the circuit so as to *increase* the number of lines of force that pass through the circuit, there will be a momentary "inverse" current induced in the circuit, and it will flow in the *negative* direction. While if the magnet were moved away the *decrease* in the number of lines of force would result in a transient "direct" current, or one flowing in the *positive* direction.

It would be possible to deduce these results from an abstract consideration of the matter from the point of view of the principle of conservation of energy. But we prefer to reserve this point until a general notion of the action of dynamo-electric machines has been given.

The following principles or generalized statements follow as a matter of the very simplest consequence from the foregoing considerations:

(*a*) To induce a current in a coil of wire by means of a magnet there must be relative motion between coil and magnet.

(*b*) Approach of a magnet to a coil or of a coil to a magnet induces currents in

the opposite direction to that induced by recession.

(*c*) The stronger the magnet the stronger will be the induced currents in the coils.

(*d*) The more rapid the motion the stronger will be the momentary current induced in the coils (but the time it lasts will, of course, be shorter).

(*e*) The greater the number of turns in the coil the stronger will be the total current induced in it by the movement of the magnet.

These points are of vital importance in the action of dynamo-electric generators. It remains, however, yet to be shown how these transient and momentary induction currents can be so directed and manipulated as to be made to combine into a steady and continuous supply. To bring a magnet pole up towards a coil of wire is a process which can only last a very limited time; and its recession from the coil also cannot furnish a continuous current since it is a process of limited duration. In the earliest machines in which the principle of magneto-electric induction was applied, the currents produced were of this momentary kind, alternating in direction. Coils of wire fixed to a rotating axis were moved past the pole of the magnet. While the coil was approaching the lines of force were increasing, and a momentary inverse current was set up, which was immediately succeeded by a momentary direct current as the coil receded from the pole. Such machines on a small scale are still to be found in opticians' shops for the purpose of giving people shocks. On a large scale alternate current machines are still employed for certain purposes in electric lighting, as for example for use with the Jablochkoff candle. Large alternate-current machines have been devised by Wilde, Gramme, Siemens, De Meritens, and others, and all of these have already been described in the pages of *Engineering*. We reserve for another article the explanation of the production of direct and continuous currents in the ordinary dynamo-electric machine.

THE ANEROID PROFILE.

By FRED. W. FLOYD, E.M.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE successful use of the Aneroid Barometer on Western surveys has led to the adoption of a method of observations and computations which is not generally known, and which it will be my endeavor to describe.

The Aneroid Profile gives the relative heights between consecutive points, the horizontal distances being measured by an odometer.

The Instruments used are: the Cistern and Aneroid Barometers, Odometer, and Psychrometer.

Cistern Barometer.—The Mountain Barometers made by James Green, New York, are used. Each one is firmly fitted into a wooden case and an outer case of leather, the latter being provided with a strap so as to be carried across the back, and thus packed it is surprising what rough experiences such a delicate instrument will survive in good condition.

The least count of the vernier is .002 inch, but by interpolating .001 inch can be estimated accurately.

To be prepared for accidents an implement box containing mercury, extra cisterns, and the necessary apparatus for refilling is provided. The additional long barometer tubes are boxed by themselves.

Aneroid Barometers.—These are made to order either by Green, or by Casella, London, diameter 3 inches.

They are compensated for differences of temperature, and are intended to be so adjusted as to read uniformly inches of mercury, at a temperature of 32° Fah. at the level of the sea in 45° latitude.

The smallest division of the scale is .05 inch, but intermediate hundredths can be estimated. A movable scale of feet is added, the zero of which is at 30 inches and graduated according to Prof.

Airy's table from —1,000 ft. to + 18,000 ft. (about 31 inches to 15 inches); being movable it can be adjusted for the error of the instrument as will be shown. Each instrument is provided with an attached thermometer, and is conveniently carried in a leather case hung over the shoulder by a strap.

Odometer.—This is an instrument devised for registering the number of revolutions of a wheel, after which, finding the number of revolutions in a mile on various kinds of roads (by experiment) the number of miles traveled is known.

It consists of a cylindrical brass box about 4½ inches diameter by 2½″ deep, with an axis in the center upon which a weight is hung, by means of an endless screw on the axis, a set of cog wheels attached to the weight registers the number of revolutions.

The metal box is covered with leather and strapped to two spokes of the odometer wheel, the weight remaining vertical while each revolution of the wheel and box is recorded on the dial plates of the cog wheels.

The Psychrometer—Consists of two thermometers of equal size and sensitiveness, if possible. One of these, called the web bulb, requires in temperate weather a single thickness of linen, and in freezing weather of fine gauze to be placed loosely around the bulb.

Ten minutes before commencing the observation immerse the covered bulb in water at temperature of the air; watch the wet bulb until it reaches its minimum reading; record this and the corresponding reading of the dry-bulb thermometer. In freezing weather the wet bulb should be covered with a thin film of ice; the gauze covering assists the formation of this, which should be melted off with tepid water before each observation, sufficient time being allowed for the re-formation of the film—the reading being taken at its minimum.

The readings are taken in *degrees* and *tenths* of a degree, the latter being estimated.

Each psychrometer is supplied with a wooden case and an outer one of leather.

2. FIELD PARTY.

It is understood that the travel is on mule back. The hypsometrical work is assigned to two men, the Meteorologist, and the Aneroid and Odometer Recorder, and both are under the immediate direction of the Topographer, in order that the determination of the vertical element of the survey may be best adapted to the general plan of the topography.

The Meteorologist carries in person the standard Cistern, and is intrusted with its important observations; makes all comparisons of Aneroids and also with the barometers of the United States Signal service when possible; sees that the other meteorological instruments are in proper condition, and prepares the final record ready for computation.

The Aneroid and Odometer Recorder has charge of the instruments indicated, and records the observations as hereafter explained. For convenience he rides the odometer mule.

OBSERVATIONS.

The initial point is the rendezvous camp, the altitude of which if not already known by spirit leveling, as when it is on a railroad, is determined from a series of hourly reading of the cistern barometer and other instruments, for as long a period as the party remains in camp, or if that is not possible, readings at 7 A.M., 2 and 9 P.M., that they may be referred by means of synchronous observations to some Signal Service Station whose elevation is known.

When in camp for one or more days, however, hourly observations should be taken day and night, for the purpose of forming tables of horary oscillation and for obtaining good aneroid errors.

Before leaving camp the error of the aneroid is determined by comparison with the cistern barometer (readings reduced to 32° Fah.) If large it is corrected as nearly as possible by means of the adjusting screw at the back of the instrument, and again compared to obtain the exact error; the zero of the movable scale is then set to the right or left of 30 inches, by an amount in inches equal to this error of the aneroid—if *too low* it is set to left of 30 inches, if *too high* to the right of 30 inches by amount of the error in inches.

At each meander station made by the Topographer, including always the stations upon entering and leaving

camp, the Odometer Recorder enters the time of day, aneroid, thermometer, and odometer readings, and the Topographer locates the point either by angles between well-fixed points, or from his meander bearings and the measured distances.

The aneroid is read in feet and inches; in feet for the convenience of the Topographer in making his field sketches, and in inches for the accurate determination of altitudes by computation; the reading in feet also serves to correct a mistake which sometimes happens—that of recording the change of inches incorrectly; it should be held vertical while being read as the weight of the instrument affects the indications and it must therefor always be read in the same position. At each station then, the odometer gives the distance traveled and the aneroid the difference in level between it and the preceding station; when camp is made at night the aneroid is compared with the cistern barometer, which indicates any change of error in the former. At important points of the meander, springs, divides, passes, &c. the cistern barometer is also read, and these comparisons serve as checks in distributing the error of the aneroid for the day.

The observations, giving the data from which the profile for the day is computed, are recorded on the following form:

FORM I.

DATE: SEPTEMBER 14, 1878. PARTY: 1; SECTION, UTAH; ———, RECORDER.
FROM CAMP NO. 24 AT CHICO, CAL., TO CAMP NO. 25 AT FOREST RAUCH, CAL.

Station.	Hour.	Aneroid. No. 6. Reading.	Temperature.	Cist. bar.* No. 1735. Reading.	Cist. bar.* No. 1735. Att'd T.	Error of Aneroid.
	A.M.					
Camp No. 24	7:30	29.64	58.5	29.798	53.8	—.084
1	8:00	29.64	62.0	..	..	..
2	8:20	29.64	65.0	..	..	..
3	9:20	29.58	67.5	..	..	..
4	9:40	29.43	70.0	..	..	..
5	10:10	29.13	74.0	..	..	..
6	10:45	28.80	75.5	..	..	..
7	11:10	28.66	76.0	..	..	..
8	11:45	28.45	76.0	..	..	..
	P.M.					
9	12:10	28.27	78.0	28.448	78.5	..
10	12:30	28.22	78.0	..	..	..
11	1:15	28.05	78.0	..	..	..
12	1:40	27.80	78.5	..	..	..
13	2:00	27.83	78.0	..	..	..
14	2:30	27.84	77.8	..	..	..
15	2:50	27.70	77.0	..	..	..
16	3:30	27.40	75.3	..	..	..
Camp No. 25	4:00	27.48	74.0	27.670	72.6	..

Station.	Odometer. Reading.	Odometer. Pr. mile.	Odometer. Miles.	Aneroid in feet.	Zero set at inches.	Remarks.
Camp No. 24	000	426		250	29.92	Chico, Butte Co.
1	447	.	1.049	250	..	
2	606	.	.373	250	..	
3	1772	.	2.737	300	..	Foot-hills.
4	2116	.	.807	425	..	
5	2644	.	1.240	700	..	
6	3148	.	1.268	1000	..	Hog Spring.
7	3545	.	.932	1125	..	
8	4029	.	1.136	1325	..	
9	4478	.	1.054	1500	..	
10	4773	.	.692	1525	..	10-mile Ho'se
11	5055	.	.662	1700	..	
12	5432	.	.885	1900	..	
13	5582	.	.352	1875	..	
14	6001	.	.984	1875	..	
15	6296	.	.692	2000	..	Toll-gate.
16	6772	.	1.117	2300	..	
Camp No. 25	7219	.	1.049	2225	..	Forest Ra'ch, Butte Co.
			17.029			

* Error of No. 1735+.006.

COMPUTATIONS.

Cistern Barometer Stations:—These embrace isolated points, such as Mountain Peaks, Divides, Passes, Towns, &c., and the camps between which the aneroid profile is run.

(*a*) All hourly series are examined by plotting the observations at 32° Fah., and erratic observations corrected by interpolation reduced to level by Col. Williamson's method, and tables of horary corrections formed for the reduction of isolated observations and for the aneroid work.

(*b*) The observations taken at the

permanent reference stations are plotted and corrected; these stations are then referred to each other by the mean of the series and their relative and absolute heights determined, provided these have not already been determined by lines of level.

(*c*) The altitudes of camps and stations where cistern barometers are read for several days are computed by referring the observations to corresponding observations at the reference stations by the mean of the series, and of all camps and other points where isolated observations are taken by daily means, the readings being corrected for horary oscillation. If camp is made for one night only the observations are computed in pairs (9 P. M. and 7 A. M. readings) with horary correction.

In order that the successive steps in the computations may be fully understood, it is thought best to give the data and reduction work necessary for a complete profile, including reference and camp stations.

Form II. gives the Reduction to Level of the observations at Prattville. Only that portion of the horary curve has been deduced, which was necessary for the hours during which the aneroid profile was run, viz., 6 A. M. to 9 P. M. (See next column.)

Having obtained the horary curve the height of barometer from daily means is used in determining the altitude of Prattville, referring to synchronous observations at the Signal office at Red Bluff, Cal., the altitude of which has been determined by R. R. levels.

For convenience the form herewith has been adopted (see page 277).

h and H are the heights of the barometer at the lower and upper stations reduced to 32° Fah., *t*, *t'* the temperatures of the air at the two stations, and *a*, *a'* the relative humidities at each point—the approximate latitude is also given.

The hypsometrical tables representing the full formula of Plantamour, found in the appendix of Lt. Col. Williamson's Treatise on the Barometer; Professional Papers, Corps of Engineers, No. 15 and represented by tables D are used.

The altitude of the camp at Chico, *from* which the profile is run, has been computed from two sets of observations and the mean of the results taken.

FORM II.—STATION: PRATTVILLE, PLUMAS CO., CAL. BAROMETER AT 32° FAH. DATE, OCT. 4 TO OCT. 13, 1878.

Day.	7 A.M.	8 A.M.	9 A.M.	10 A.M	11 A.M	12 M.	1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.	7 P.M.	8 P.M	9 P.M.	6 A.M.	Daily mean.
October 4th	25.622	25.626	25.632	25.618	25.607	25.588	25.577	25.567	25.552	25.554	25.556	25.564	25.572	25.596	25.615	25.659	
" 5th	.660	.673	.664	.645	.634	.610	.601	.593	.578	.574	.578	.592	.606	.614	.628	.665	
" 6th	.673	.678	.675	.651	.648	.621	.604	.598	.584	.581	.578	.581	.597	.608	.620	.620	
" 7th	.625	.622	.619	.603	.585	.555	.524	.525	.508	.504	.505	.504	.517	.521	.527	.546	
" 8th	.550	.557	.556	.544	.537	.519	.498	.483	.470	.465	.467	.463	.470	.477	.474	.410	
" 9th	.417	.426	.423	.406	.410	.399	.396	.401	.435	.436	.434	.440	.468	.484	.503	.577	
" 10th	.587	.608	.628	.618	.608	.592	.574	.563	.554	.551	.548	.551	.569	.570	.585	.562	
" 11th	.581	.583	.573	.554	.532	.508	.483	.467	.463	.456	.457	.471	.473	.465	.464	.481	
" 12th	.483	.504	.510	.494	.503	.479	.480	.492	.484	.479	.479	.482	.464	*.468	.472	.496	
" 13th	25.496																
Sum	5198	5277	5280	5133	5064	4871	4737	4689	4643	4600	4602	4648	4736	4803	4888	5016	
Reduction to level	.000	.005	.010	.016	.021	.026	.031	.037	.042	.047	.052	.058	.063	.068	.073	.121	
Sum reduced to level	5198	5282	5290	5149	5085	4897	4768	4726	4685	4647	4654	4706	4799	4871	4961	5137	
Mean	25.578	.587	.588	.572	.565	.544	.530	.525	.521	.516	.517	.523	.533	.541	.551	.571	
Grand mean	25.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	.548	
Horary correction	— .030	— .039	— .040	— .024	— .017	+ .004	+ .018	+ .023	+ .027	+ .032	+ .031	+ .025	+ .015	+ .007	— .003	— .023	

*Observation not taken.

FORM III.

Names of Tables, &c.	Computation.	Computation.	Computation.	Computation.
Date, 1878.....	Oct. 4 to 12.	Aug. 6 to 9.	Sept. 11 to 14	Sept. 15 and 15. 2.
No. of Synchronous Obs..	Daily Means.	Daily Means.	Daily Means.	
Lower Station.....	Red Bluff.	Camp 1 (24) Chico, Cal.	Camp 24 (1) Chico, Cal.	Red Bluff.
Upper Station.....	36, Prattville.	Red Bluff.	Red Bluff.	Camp 25 Forest Ranch.
Bar at 32° h=	29.552	29.645	29.722	29.484
Bar at 32° H=	25 247	29.477	29.555	27.548
Temperature t_1=	69.2	75 2	69.6	67.1
Temperature t'=	48.5	83.6	75.6	44.7
$t+t'$=	117.7	158 8	145.2	111.8
Humidity a = ...	.470	.447	.428	.494
Humidity a' = ...	.643	.364	.405	.481
$a+a'$=	1.113	.811	.833	.975
Latitude = ...	40° 20′	40 00	40 00	40 00
D_i (h) = ...	28416.1	28498.4	28566.5	28355.7
D_i (H)=	24596.9	28349.4	28418 7	26574.5
1st Approx.....	3819.2	149.0	147.8	1781.2
D_{ii} = ...	208.9	14.4	12.2	86.7
2d Approx.....	4028.1	163.4	160.0	1867.9
D_{iii} = ...	1.8	0.0	0.0	0 9
D_{iv} = ...	10.9	0.4	0.4	4.9
D_v = ...	0.1	0.0	0.0	0.2
3d Approx.....	4040.9	163.8	160.4	1873.9
D_{vi} = ...	41.0	2.0	2.0	19.0
D_{vii}=	13.7	1.4	1.1	5.7
Correct for $(a+a')$=	15.2	1.1	0.9	5.5
Diff. of Altitude = ...	4056.1	164.9	161.3	1879.4
Alt. of Reference Station=	338.0	338 0	348.0	338.0
Altitude of Station = ...	4394.1	173.1	176.7	2217.4
Remarks.....		Adopt for Chico, 174.9.		

The altitude of Camp 25, *to* which the profile is run, was obtained from the mean of 9 P. M. and 7 A. M. readings of the C.B., reduced to 32°, and the horary correction applied.

Aneroid Barometer Stations:—Having determined the altitude of camps 24 and 25, the profile between can be computed, the observations as shown in Form I., are transcribed on Form IV., in columns 1, 2, 3, 4, 10 and 20 (see page 278).

The readings of the C.B. are then reduced to 32° Fah., and corrected for instrumental error, and the correction for the error of the aneroid determined.

On leaving camp at 7.30 A. M. the error was −0.084 ins., at 12.30 P. M. when the next comparison was made it was −0.095; a mean of the two is therefore assumed for that portion of the day and a correction of +0.090 applied.

On entering camp at 4 P. M. the error was −0.076, and the mean of this and the previous comparison gives −0.086, thus indicating that the aneroid had maintained a nearly constant error during the day. The horary curve as previously determined at Prattville is next applied, interpolating where necessary, to reduce the observations to the mean of the day. The algebraic sum of these corrections for each station gives the "total correction" to be applied to the respective readings. Each station is referred to the preceding one by means of Col.

FORM IV.—DATE: SEPTEMBER 14, 1878. CAMP No. 24 TO No. 25.

Station.	Hour.	Aneroid No. 6. Reading.	Cist. Bar. No. 1735. Error +.006. Reading.	Att. Th.	Bar. at 32°	Correct for error of Aneroid.	Correct for Hor. Oscil.	Total correction.	Correct readings.	Temperature.	$t+t'$	D_1 (h—H)	1st Approx. diff. of altitude.	D_{11}	2d Approx. diff. of altitude.	Altitude.	Distribution of error.	Altitude above sea level.	Diff. of altitude between stations.	Distance in miles.	Remarks.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
	A.M.																				
Camp No. 24	7:30	29.64	29.798	53.8	29.724	+.090	−.034	+.056	29.696	55.5	146°	28543.5	Altitude by Cis. Bar.			174.9	..	174.9	..	..	Chico, Butte Co., Cal.
1	8:00	29.64	..	..	..	+.090	−.039	+.051	.691	62.0	..	28539.1	+ 4.4	0 2	+ 4.6	179.5	-3.2	176.3	1.4	1.049	Chico P. O.
2	8:20	29.64	..	..	..	+.090	−.039	+.051	.691	65.0	..	28539.1	0.0	0.0	0 0	179.5	6.4	173.1	3.2	.373	
3	9:20	29.58	..	..	..	+.090	−.035	+.055	.635	67.5	..	28489.6	+ 49.5	4.7	+ 54 2	233.7	9.6	224.1	51.0	2.737	Foot-hills.
4	9:40	29.43	..	..	..	+.090	−.030	+.060	.490	70.0	..	28361.0	+128.6	11.7	+140.3	374.0	12 8	361.2	137.1	.807	
5	10:10	29.13	..	..	..	+.090	−.023	+.067	29.197	74.0	..	28099.0	+262.0	23.8	+285.8	659.8	16.0	643.8	282.6	1.240	
6	10:45	28.80	..	..	..	+.090	−.019	+.071	28.871	75 5	..	27804.7	+294.3	26.8	+321.1	980.9	19.2	961.7	317.9	1.268	Hog Spring.
7	11:10	28.66	..	...	..	+.090	−.014	+.076	.736	76.0	..	27681.8	+122.9	11.2	+134.1	1115.0	22.4	1092.6	130.9	.932	
8	11:45	28.45	..	..	..	+.090	−.002	+.088	.538	76.0	..	27500.5	+181.3	16.5	+197.8	1312.8	25.6	1287.2	194.6	1.136	
	P.M.																				
9	12:10	28.27	..	..	..	+.090	+.007	+.097	.367	78.0	..	27342.7	+157.8	14.4	+172.2	1485.0	28.8	1456.2	169.0	1.054	
10	12:30	28.22	28.448	78.5	28.315	+.090	+.012	+.102	.322	78.0	..	27301.1	+ 41.6	3.8	+ 45.4	1530.4	32.0	1498.4	42.2	.692	10-mile House.
11	1:15	28.05	..	..	..	+.086	+.019	+.105	28.155	78.0	..	27146,0	+155 1	14.1	+169.2	1699.6	35.2	1664.4	166.0	.662	
12	1:40	27.80	..	..	..	+.086	+.021	+.107	27.907	78.5	..	26914.2	+231.8	21.1	+252.9	1952.5	38 4	1914.1	249.7	.885	
13	2:00	27.83	..	..	..	+.086	+.023	+.109	.939	78.0	..	26944.3	− 30.1	2.7	− 32.8	1919.7	41.5	1878.2	35.9	.352	
14	2:30	27.84	..	..	..	+.086	+.025	+.111	.951	77.8	..	26955.5	− 11.2	1.0	− 12.2	1907.5	44.6	1862.9	15.3	.984	
15	2:50	27.70	..	..	..	+.086	+.026	+.112	.812	77.0	..	26824.7	+130 8	11.9	+142.7	2050.2	47.7	2002.5	139.6	.692	Toll-gate.
16	3:30	27.40	..	..	..	+.086	+.030	+.116	.516	75.3	..	26544.0	+280.7	25.6	+306.3	2356.5	50.8	2305.7	303.2	1.117	
Camp No. 25	4:00	27.48	27.670	72.6	27.556	+.086	+.032	+.118	27.598	74.0	..	26622.1	− 78.1	7.1	− 85.2	2271.3	53.9	2217.4	88.3	1.049	For'st Rauch, Cal.
												Altitude of Camp No. 2 by Cis. Bar. 2217.4								17.029	
												Error in Aneroid Profile..... +53.9 ft.									

Williamson's Tables D, for computing differences of altitude, and thus the first approximate difference of altitude between stations is obtained. The temperature term is next considered; instead of $t+t'$ being taken separately for each pair of stations, the operation is shortened by taking twice the average of the several temperature readings during the meander. These corrections (Col. 14) are obtained from tables giving values of the factor $\frac{t+t'-64}{900}$, and is different from the temperature term used in connection with corrections for humidity.

Beginning at camp, the successive differences of altitude between the meander stations is then added, each to the altitude of the station preceding, and the profile carried over to the next camp by successive steps. The difference between this altitude and that of the computed cistern altitude is the error to be distributed throughout the profile, to make it *close;* in distributing the error it is assumed that the non-periodic * oscillation is uniform during the few hours in which the profile is run, and that this error in the altitude of each station is directly proportional to the time. Usually it is sufficient to divide the error equally between the various stations, as has been done in this case.

The method herein described for obtaining Aneroid Profiles has been in use by the War Department Surveys, under Capt. Wheeler, Corps of Engineers, since 1874, and has become a distinctive feature of that work. When the meander is from fifteen to twenty miles a day the running of the usual line of level is out of the question; formerly the cistern barometer was entirely relied upon, but the time occupied in a single reading when the instrument has to be screwed up, inverted and packed after each reading, rendered only a few observations possible.

The results now obtained have proved entirely satisfactory for the scale upon which the topographical maps are constructed (1 inch to 8 miles or 1 : 506,880), and indicate that the Aneroid Barometer used in connection with the Mercurial is the most practicable instrument in surveying for preliminary routes for wagon or railroad, and for rapid contouring, and is an indispensable, and *not*, as is frequently believed, an unreliable instrument to the engineer.

* As opposed to the periodic or horary oscillation.

REPORT ON THE CASTOR-OIL GAS WORKS OF JEYPORE, INDIA.

By MAJOR S. S. JACOB, B.S.C., Assoc. Inst. C.E., Exec. Eng.

From Professional Papers on Indian Engineering, Roorkee, April, 1881.

In this paper the author first gives general results, showing the cost of the construction of the Jeypore gasworks, and of the manufacture of gas made from castor oil, from Sept. 1, 1879, to Sept. 1, 1880, and then supplements his Report with a statement of details prepared by the resident superintendent, Mr. Tellery, of whose management he speaks in terms of warm eulogy.

The gasworks, including apparatus, pipes, lamp posts, &c., were built by contract for the sum of 317,822 rupees, and produced during the year 1879–80 1,184,644 cubic feet of gas, at a cost for material used of 23r. 2a. 5p. per 1,000 cubic feet during the first half-year, and of 18r. 1a. 8p. per 1,000 cubic feet during the second half-year; but if the expenses of the establishment and salaries (7387 rupees for the whole year) are included, these figures become respectively 29r. 7a. 8p. and 26r. 15a. 7p. per 1,000 cubic feet.*

The average daily number of jets for the first six months was four hundred and seven, and for the last six (the summer) months three hundred and seventy-five, and each jet is stated to consume $1\frac{3}{4}$ cubic foot per hour, the cost of each jet per night of six hours having been $6\frac{3}{4}$d.

* These figures are exactly as given in the report. In this abstract where rupees have been converted into English money the nominal exchange of 1 rupee =2 shillings has been adopted.

An oil gas-burner consuming 1 cubic foot per hour will give as much light as a coal gas-burner consuming $2\frac{1}{2}$ cubic feet per hour. Castor oil is chiefly used; but this is supplemented with other oils, such as poppy, til, and rape oil, when procurable at more favorable rates. Mr. Tellery has taken much pains to increase the cultivation of the castor plant, and personally superintended the sowing of about 300 acres in the neighborhood of Jeypore.

One maund (82 lbs.) of castor oil produces 750 cubic feet of gas of $26\frac{1}{2}$-candle power, or 1,000 cubic feet of $18\frac{1}{2}$-candle power, or 1,250 cubic feet of 9-candle power.* The other oils produce 610 cubic feet of the first, 762 cubic feet of the second, and 914 cubic feet of the third quality of gas, so that the gas made from castor oil is the cheapest, although it costs £1 3s. 6d. per maund and the other oils only £1 per maund.

The apparatus (patented by Professor Herzel of Leipzig, Germany) originally consisted of two sets of six retorts each in a separate oven, and oil gas was made in three retorts, whilst water was decomposed and hydrogen gas produced in the other three retorts. But Mr. Tellery soon found it advisable to dispense with the hydrogen retorts, which increased the cost of wear and tear; he also decided to set each retort separately, and now works two retorts at a time, which generate gas on an average during two hundred and eighteen hours monthly, producing 98,720 cubic feet, at a cost for wear and tear, fuel, stokers, and purification (exclusive of the cost of oil), of 4r. 4a. $4\frac{3}{4}$p. per 1,000 cubic feet, which Mr. Tellery believes might be reduced to 2r. 9a. $5\frac{3}{4}$p., if the consumption should increase to 260,000 cubic feet per month.

From 33 to 40 per cent. of oil are extracted from the castor seed, the shells being first broken off in a crusher, and separated by hand from the seed, which is then crushed to a paste, heated in pans, and, lastly, packed in horsehair bags and pressed hot in hydraulic oil presses, each of which produce about $7\frac{1}{2}$ maunds (615 lbs.) weight of oil per diem.

The process of manufacturing the gas is as follows:

The retorts have first to be heated from six to eight hours, till they are sufficiently hot to decompose the oil and generate gas favorably. Then the oil is passed from above into the retort through a siphon, taking care that no more oil shall enter than the retort can instantly decompose, as otherwise it would distil over as vapor, and very little useful gas would be generated; but if too little oil enters the retort, then the gas, although more in quantity, is of a poorer quality, which also must be guarded against. A good deal of tar and ammoniacal liquor is deposited in a hydraulic cylinder after the gas first leaves the retorts, and more on its passage through a square cooling vessel, after which the gas passes into two coke towers, and from thence into purifiers filled with dry lime, sulphate of iron and copper, and sheep's wool saturated in naphtha and sawdust, which clears it of its carbonic acid; and from here it passes in a purified state into the gas-holder.

It is proposed to utilize the tar (for which there is not sufficient sale) by burning it for lampblack.

Some buildings have been lighted temporarily by means of portable wrought-iron tanks, into which the gas is compressed at a pressure of about 50 lbs. to the square inch, and conveyed by cart to the spot where it is stored in small gas-holders. On one occasion, after being so stored for nine months, the gas burned as bright and clear as when first made.

* Respectively 21,000, 28,000, and 35,000 cubic feet per ton of oil.

In one form of secondary battery M. J. Rousse uses for the negative electrode a sheet of palladium, which during the electrolysis absorbs more than 900 times its volume of hydrogen; at the positive pole he uses a sheet of lead; the electrolyte being a 10 per cent. solution of sulphuric acid. Another form giving good results is produced by making the negative electrode of thin sheet iron, which absorbs more than 200 times its volume of hydrogen when electrolyzed in a 50 per cent. solution of sulphate of ammonia. The positive pole is formed of a sheet of lead covered with a layer of litharge. Platinum and palladium are too dear, unless used to platinumize or palladiumize other substances for electrodes.

THE THEORY AND PRACTICE OF VENTILATING COAL MINES.

By W. FAIRLEY, M.E., F.S.S.

II.

THE EFFECT OF SPLITTING THE AIR.

32. In this place it seems desirable to explain what is meant by "splitting the air." Originally it was the usual custom to circulate the air through a mine in one undivided current, down one shaft, around the workings, and up the other shaft, and this plan is still in use in some simple cases. When this one current is divided in the mine into two or more currents, which unite again at or before reaching the upcast, it is said to be split. Splits may be of equal or unequal length and area. The expression "two equal splits" means that the original one current is divided into two currents, each of half the length, but both with the same area as the original one. It must be noted that the phrase "equal splits" is more a mathematical than a practical one, for it may be safely said that to split a current into two, three, or more equal dimensions is never done practically; it can, however, in some cases be done nearly. After this explanation it will be understood that theoretical splitting will always show a somewhat better result than practical splitting, because, owing to the varied circumstances of the mine, the air cannot always be exactly equally divided, and in practice, as a rule, the aggregate length of the various splits will be somewhat longer than the original one current; or the splitting will take place too far in-bye, or reunite again too far away from the bottom of the upcast. No one understood this better than the late Mr. Atkinson; hence he says:—"Every principal split of air should commence as near as possible to the bottom of the downcast shaft, and should have a distinct airway to return in."

In the calculations which will be brought forward in this chapter with reference to splitting, it will be on the assumption that the splits take place at the bottom of the downcast, and re-unite at the bottom of the upcast—in fact that the splits are equal. Unequal splitting will be taken into consideration in the next section.

Suppose the original aircourse of the mine to measure 40 ft. area (a), and 120,000 rubbing surface (s); by splitting into two equal currents we should get two airways each 40 ft. area (a) and 60,000 rubbing surface; by splitting into three currents we should have three airways, each 40 ft. area and 40,000 rubbing surface; the area, after splitting, being two or three times that of the original airway, according to the number of splits, but the total rubbing surface remaining the same throughout.

It is necessary here to explain further that when this original one current is divided into two equal splits, they may be considered as one current with double the area, but with the same rubbing surface. When divided into three equal splits, these three divisions may be considered as one airway of treble the original area, but with the same rubbing surface, in fact, as tabulated below:

	a.	s.
Original current.....	40	120,000
Two equal splits..... 1...	40	60,000
Two equal splits..... 1...	40	60,000
Equal one current.....	80	120,000
Three equal splits..... 1...	40	40,000
Three equal splits..... 1...	40	40,000
Three equal splits..... 1...	40	40,000
Equal one current.....	120	120,000

This will be proved arithmetically further on.

33. The benefit derived from splitting depends very much upon the relative rubbing surfaces and the areas of the shafts, as compared with those of the mine, and unless the friction due to the shafts be taken into account when the effect of splitting is calculated, the result will be fallacious.

Were it not for the resistance of the shafts, which, of course, varies with the quantity of air passing, the result of splitting would be more easily calculated.

34. It may perhaps be better, for the sake of the student, that we should in the first place consider the effect of splitting without taking into account the shaft resistances, so that he may acquaint himself gradually with the process of calculation, and eventually see the difference of the two results.

35. The following example is given for calculation: the quantity of air passing round a mine in one current before splitting is 10,000 cubic feet per minute; the area of the aircourse is 20 ft., and the rubbing surface is 24,000, what quantity will circulate when the current is split into 2, 3, 4, 5, 6, and 10 equal divisions, the pressure remaining the same?

In the first place the pressure (p) for the one current may be found by the rule $\frac{ksv^2}{a}$, this will be 6.51 lbs. The effect of splitting into 2, 3, &c., divisions, as has been explained in paragraph 31, is to double, treble, &c., the area, without altering the rubbing surface, and as the quantity is obtained by the rule $\sqrt{\frac{pa}{ks}} \times a$, we use this to find the quantities with the various splits in operation; but as p, k, and s are the same in all these instances, the formula will be reduced to this simple rule $\sqrt{a} \times a$, and the relative quantities will be according to the square root of the area multiplied by the area, as tabulated below:

No. of splits.	s.	a.	$q = \sqrt{\frac{pa}{ks}} \times a$.	$p = \frac{ksv^2}{a}$
1	24,000	20	10,000	6.51
2	24,000	40	28,284	6.51
3	24,000	60	61,961	6.51
4	24,000	80	80,000	6.51
5	24,000	100	111,803	6.51
6	24,000	120	146,969	6.51
10	24,000	200	316,228	6.51

or the question may be worked out without reference to the actual dimensions of the areas and rubbing surfaces in each case, further than considering the areas to vary as 1, 2, 3, 4, &c. Then the quantities that will pass will be most simply found thus:—If $\sqrt{1} \times 1 : 10{,}000 :: \sqrt{2} \times 2 : = 28{,}284$, the quantity with two splits, and if $\sqrt{1} \times 1 : 10{,}000 :: \sqrt{10} \times 10 : = 316{,}228$, the quantity with ten splits as above.

An example similar to this is given further on, showing what the result will be after taking into account the shaft resistances.

36. If the power is to remain the same, instead of the pressure, and the original aircourse passing 10,000 cubic feet per minute, the quantity that will pass in each case of 2, 3, 4, 5, 6, and 10 equal splits will be simply in direct proportion to the area:—1, 10,000; 2, 20,000; 3, 30,000; 4, 40,000; 5, 50,000; 6, 60,000; 10, 100,000. The rule to find the quantity when the power (u) is given being $\sqrt[3]{\frac{u}{ks}} \times a$, but k, s and u being the same in the case of all the splits, these may be canceled, and the quantities will be directly according to the area as stated above.

37. There is a great difference between splitting the air and adding an additional aircourse of the same length and area as the original one; thus, in dividing one current into two equal splits, we get an increase from 10,000 to 20,000 with the same power, but by adding an additional aircourse the increase will only be from 10,000 to 15,874; this may be worked out as follows:

Take a to equal 36 and s to equal 18,000, then the power is found by the formula $\frac{ksv^2q}{a} = 8371.4$ foot pounds $= u$. With the additional aircourse "a" and "s" will be doubled, and as the velocity is got by $\sqrt[3]{\frac{u}{ks}}$, we use these figures $\sqrt[3]{\frac{8371.4}{.0000000217 \times 36000}} \times 72$, to get the quantity which is equal to 15,874 cubic feet per minute, or the quantity is according to the reciprocal of the cube root of the rubbing surface multiplied by the area; as both s and a are in the proportion of one to two we say,

If $\sqrt[3]{\frac{1}{1}} \times 1 : 10{,}000 :: \sqrt[3]{\frac{1}{2}} \times 2 : = 15{,}874$, the same as above.

38. So far, we have not taken into account the shaft resistances, but in the next example we will do so.

If there are 10,000 cubic feet of air passing through a mine in one current, the resistances of the shafts at that time being equal to the resistance of the mine, what extra quantity of air will pass through the mine by adding an additional aircourse, same length and area as the original one, the power remaining the same?

In order to make the resistance of the shafts and mine equal, take the area and rubbing surface of each the same. With the addition of another aircourse, both the area and rubbing surfaces in the mine are doubled. Proceeding in this way, the results have been obtained as below:

Divisions of air.		q.	a.	s.	p.	u.
1	Shafts..	10,000	36	18,000	.83714	8371.4
	Mine ...	10,000	36	18,000	.83714	8371.4
	Total...			36,000		16742 8
2	Shafts..	11,694	36	18,000	1.1455	13394.3
	Mine ...	11,694	72	36,000	.28662	3348.5
	Total...					16742.8

Having taken the area of the shaft and mine at 36, and rubbing surface of each at 18,000 with one current, we find that the power required to pass 10,000 ft. through the mine and shafts amounts to 16742.8 foot pounds (u). The value of p is obtained by

$$\frac{\left(\frac{q}{a}\right)^2 \times s \times k}{a}, \text{ and of } u \text{ by } qp.$$

Now, in order to apportion the power that will be used up by the shaft and mine after making the additional aircourse, we put the two aircourses of the mine into one, the dimensions of which will be 72 a and 36,000 s; and use the formula given in paragraph 30, viz., $\left(\frac{1}{a}\right)^3$.

By this we find 13394.3 units are required to pass the same quantity of 11,694 cubic feet per minute through the shafts that 3348.5 units will pass through the mine. Or, the power used in the shafts will be found thus:

$$\frac{16742.8 \times 18000 \times \left(\frac{1}{36}\right)^3}{18000 \times \left(\frac{1}{36}\right)^3 + 36000 \times \left(\frac{1}{72}\right)^3} = 13394.3$$

that of the mine thus:

$$\frac{16742.8 \times 36000 \times \left(\frac{1}{72}\right)^3}{18000 \times \left(\frac{1}{36}\right)^3 + 36000 \left(\frac{1}{72}\right)^3} = 3348.5$$

Total..... 16742.8

39. If the resistances of the shafts are half those of the mine when there are five equal splits, and there are 10,000 ft. of air passing in one current before being split at all, the quantities that will pass through the mine with 2, 3, 4, 5, 6, and 10 equal splits are stated in the table on page 284, the same ventilating pressure being in operation.

In this table it is shown that, with six equal splits and area taken at 120, and rubbing surface 24.000 the pressure required to pass 107,863 ft. through the mine is 3.50645. Here we have taken the six equal splits as one current, and to show that this one current would be equal to the six splits taken collectively we give the following figures:

	s.	a.	p.	q.
6 equal splits =	4000	20	3.50645	17977⅓
	4000	20		17977⅓
	4000	20		17977⅓
	4000	20		17977⅓
	4000	20		17977⅓
	4000	20		17977⅓

All the splits are reckoned to be divided at the bottom of the downcast, and to re-unite at the bottom of the upcast. They are therefore all to be considered as subject to one common pressure; taking this for each at 3.50645, and using the formula $\sqrt[2]{\frac{pa}{ks}} \times a$, we shall find that each separate split will pass 17977⅓ ft., and the total quantity in the six splits will be 107,863 ft., and therefore one current having $s = 24{,}000$ and $a = 120$ is equal to six divisions taken together, each of them having $s = 4000$ and $a = 20$.

Here a of shafts has been made to equal 100 and $s = 12{,}000$, and of mine when there are five splits $a = 100$, $s = 24{,}000$, for by these conditions we shall

Division of the current.	Relatively.			Actual.			
	s.	a.	$p = \frac{s\left(\frac{1}{a}\right)^2}{a}$	s.	a.	p.	$q = \sqrt[2]{\frac{pa}{ks}} \times a$
	1.	2.	3.	4.	5.	6.	7.
1 { Shafts.....	1	10	.001	12,000	100	.02604	10,000
1 { Mine.....	2	2	.25	24,000	20	6.51	10,000
			.251			6.53604	
2 { Shafts.....	1	10	.001	12,000	100	.20267	27,898
2 { Mine.....	2	4	.03125	24,000	40	6.33337	27,898
			.03225			6.53604	
3 { Shafts.....	1	10	.001	12,000	100	.63710	49,463
3 { Mine.....	2	6	.009259	24,000	60	5.89894	49,463
			.010259			6.53604	
4 { Shafts.....	1	10	.001	12,000	100	1.33219	71,526
4 { Mine.....	2	8	.00390625	24,000	80	5.20385	71,526
			.00490625			6.53604	
5 { Shafts.....	1	10	.001	12,000	100	2.17868	91,469
5 { Mine.....	2	10	.002	24,000	100	4.35736	91,469
			.003			6.53604	
6 { Shafts.....	1	10	.001	12,000	100	3.02959	107,863
6 { Mine.....	2	12	.0011574	24,000	120	3.50645	107,863
			.0021574			6.53604	
10 { Shafts.....	1	10	.001	12,000	100	5.22883	141,704
10 { Mine.....	2	20	.00025	24,000	200	1.30721	141,704
			.00125			6.53604	

have the resistances of the shafts half those of the mine when there are five equal splits, as desired in the question. In explanation of the figures given under columns s, a, and p "relatively," it may be said that the rubbing surfaces of the shafts and mine are in the proportion of 1 and 2, both in the case of the one current, and all the splits and the areas are in the proportions given in the second column; the third column shows the relative pressure required to pass equal quantities through airways having the conditions given in columns 1 and 2. With reference to the figures in column 6, they are obtained by apportioning them according to their relative pressures in the third column; thus, the pressure per foot at work in producing the ventilation is 6.53604 lbs., when 10,000 ft. pass in the one current, the result being got at by working out both for the shafts and mine the rule $\frac{\left(\frac{q}{a}\right)^2 \times s \times k}{a}$; and we say, for example, in the case of two splits, if .03225 give 6.53604, what will .001 give? and, if .03225 give 6.53604, what will .03125 give? by which we obtain .20267, the pressure required in the shafts, and 6.33337, the pressure required for an equal quantity of air in the mine; and so for the other splits. The quantity in the seventh column is obtained by $\sqrt[2]{\frac{pa}{ks}} \times a$; or the result may be determined more directly by using the relative pressures obtained in column 3; the quantities will be according to the square root of these, thus:

$$\text{With 2 splits} = \frac{\sqrt{\frac{.001}{.03225}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 27898.$$

$$\text{With 3 splits} = \frac{\sqrt{\frac{.001}{.010259}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 49463.$$

$$\text{With 4 splits} = \frac{\sqrt{\frac{.001}{.00490625}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 71526.$$

$$\text{With 5 splits} = \frac{\sqrt{\frac{.001}{.003}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 91469.$$

$$\text{With 6 splits} = \frac{\sqrt{\frac{.001}{.0021574}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 107863.$$

$$\text{With 10 splits} = \frac{\sqrt{\frac{.001}{.00125}} \times 10000}{\sqrt{\frac{.001}{.251}}} = 141704.$$

40. Considering the resistances of the shaft and mine in the same proportion as in the previous example, but reckoning the power to remain the same throughout, the accompanying table shows the quantity that will pass with the various splits.

Having explained in the remarks on the previous table how the quantities have been found, it seems unnecessary to do so in this case; indeed, the tables are so constructed as to obviate as much as possible the necessity of explanation. The results given in this table may be found more directly by using the relative powers in the third column of the table; the quantities will be according to the cube root of these:

$$\text{With 2 splits} = \frac{\sqrt[3]{\frac{.001}{.03225}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 19817.$$

$$\text{With 3 splits} = \frac{\sqrt[3]{\frac{.001}{.010259}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 29030.$$

$$\text{With 4 splits} = \frac{\sqrt[3]{\frac{.001}{.00490625}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 37123.$$

Divisions of the current.	Relatively.			Actual.			
	s.	a.	$s\left(\frac{1}{a}\right)^3 = u$.	u.	s.	a.	$q = \sqrt[3]{\frac{u}{k\,s} \times a}$
	1.	2.	3.	4.	5.	6.	7.
1 { Shafts.....	1	10	.001	260.4	12,000	100	10,000
1 { Mine.....	2	2	.25	65100.	24,000	20	10,000
			.251	65360.4			
2 { Shafts.....	1	10	.001	2026.7	12,000	100	19,817⅓
2 { Mine.....	2	4	.03125	63333.7	24,000	40	19,817⅓
			.03225	65360.4			
3 { Shafts.....	1	10	.001	6370.4	12,000	100	29,030
3 { Mine.....	2	6	.009259	58990.	24,000	60	29,030
			.010259	65360.4			
4 { Shafts.....	1	10	.001	13322.5	12,000	100	37,123
4 { Mine.....	2	8	.00390625	52037.9	24,000	80	37,123
			.00490625	65360.4			
5 { Shafts.....	1	10	.001	21786.8	12,000	100	43,737
5 { Mine.....	2	10	.002	43573.6	24,000	100	43,737
			.003	65360.4			
6 { Shafts.....	1	10	.001	30295.9	12,000	100	48,818
6 { Mine.....	2	12	.0011574	35064.5	24,000	120	48,818
			.0021574	65360.4			
10 { Shafts.....	1	10	.001	52288.3	12,000	100	58,558
10 { Mine.....	2	20	.00025	13072.1	24,000	200	58,558
			.00125	65360.4			

$$\text{With 5 splits} = \frac{\sqrt[3]{\frac{.001}{.003}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 43737.$$

$$\text{With 6 splits} = \frac{\sqrt[3]{\frac{.001}{.0021574}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 48818.$$

$$\text{With 10 splits} = \frac{\sqrt[3]{\frac{.001}{.00125}} \times 10000}{\sqrt[3]{\frac{.001}{.251}}} = 58558.$$

41. Mr. Atkinson, in his *Treatise on Ventilation*, gives the quantities that will pass "supposing a mine to have such shafts and airways that when there are five equal splits of air the shaft resistances amount to one half of the resistances offered by the mine . . . if before splitting the air at all we had a ventilation of 10,000 cubic feet of air per minute," with the same ventilating pressure in force (see page 59, fourth edition). As the figures are different from those obtained above, we have brought them into a tabular form, and worked out the pressure (p) from the formula $\frac{k\,s\,v^2}{a}$ as below.

It may be submitted that had Mr. Atkinson's quantities been correct, the pressure (p) should have been the same all the way down in the table; but it will be seen that the results are slightly different.

42. Again we have brought Mr. Atkinson's figures of page 60, fourth edition, into a tabular form and applied the rules $u=q\ p=vap$ to ascertain the power, and find the results are not quite the same in each case, though the difference is not very much, as will be seen from the last column of the table on this page.

Divisions of the current.	s.	a.	q, as per Mr. Atkinson.	$p=\frac{ksv^2}{a}$	Divisions of the air current.	s.	a.	q, as per Mr. Atkinson.	$p=\frac{ksv^2}{a}$	$u=qp=vap$
1 Shafts.	12,000	100	10,000	.02604	1 Shafts.	12,000	100	10,000	.026	260.4
1 Mine..	24,000	20	10,000	6.51	1 Mine..	24,000	20	10,000	6.51	65100.
				6.53604						65360.4
2 Shafts.	12,000	100	27,892	.20258	2 Shafts.	12,000	100	19,813	.1022	2025.31
2 Mine..	24,000	40	27,892	6.33067	2 Mine..	24,000	40	19,813	3.1940	63291.
				6.53325						65316.31
3 Shafts.	12,000	100	49,449	.63673	3 Shafts.	12,000	100	29,022	.2193	6365.
3 Mine..	24,000	60	49,449	5.89566	3 Mine..	24,000	60	29,022	2.0308	58938.
				6.53239						65303.
4 Shafts.	12,000	100	71,527	1.33223	4 Shafts.	12,000	100	37,121	.3588	13319.
4 Mine..	24,000	80	71,527	5.20407	4 Mine..	24,000	80	37,121	1.4016	52028.
				6.53630						65347.
5 Shafts.	12,000	100	90,789	2.14638	5 Shafts.	12,000	100	43,736	.4981	21785.
5 Mine..	24,000	100	90,789	4.29277	5 Mine..	24,000	100	43,736	.9962	43570.
				6.43915						65355.
6 Shafts.	12,000	100	107,800	3.02607	6 Shafts.	12,000	100	48,797	.6200	30254.
6 Mine..	24,000	120	107,800	3.50236	6 Mine..	24,000	120	48,797	.7176	35017.
				6.52843						65271.
10 Shafts.	12,000	100	141,710	5.22928	10 Shafts.	12,000	100	58,556	.89286	52282.
10 Mine..	24,000	200	141,710	1.30732	10 Mine..	24,000	200	58,556	.22321	13070.
				6.53660						53526.

42a. A number of uneven splits subject to common pressure may be converted to one typical road that will offer the same resistance in passing the same quantity of air, in the following manner:

Let r=the sum of the separate results for each split of—

$$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$$

Let a'=the area of the new typical road,
" s'=rubbing surface of ditto, then

$$\frac{\left(\frac{1}{r}\right)^2 \times a'}{\left(\frac{1}{a'}\right)^2} = s'$$

EXAMPLE:—Reduce the three uneven splits below to one road 6 ft. square that will offer the same resistance with the same quantity, or pass an equal quantity with the same pressure.

	a.	s.	$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$
1	30	59400	.674201
2	36	57600	.900009
3	35	72000	.771678
			2.345888

$$\text{Then } \frac{\left(\frac{1}{2.34588}\right)^2 \times 36'}{\left(\frac{1}{36}\right)^2} = 8478\ s.$$

or $\frac{8478}{24} = 344\frac{1}{12}$; thus, a road 6 ft. square of this length or having a rubbing surface of 8478, will be equal to the three divided roads above.

Another example may be given to illustrate this rule. There are five unequal splits subject to one common pressure, with dimensions as below; find the value of s for a road 6 ft. square to give a resistance equal to that of all the splits together:

No.	Size.	Length.	$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}}$
	ft. ft.		
1	8 × 3	1500	.6472313
2	5 × 5	1300	.7752171
3	4 × 5	1200	.6085806
4	6 × 6	1000	1.3942729
5	5 × 5	1300	.7752171
			4.2005190

$$\text{Then } \frac{\left(\frac{1}{4.200519}\right)^2 \times 36'}{\left(\frac{1}{36}\right)^2} = 2644.24\ s.,$$ the answer.

TO FIND THE QUANTITY THAT WILL RESULT FROM THE APPLICATION OF A GIVEN PRESSURE OR POWER IN A MINE HAVING UNEQUAL SPLITS, &c.

43. If there are a number of equal or unequal splits in a mine, all subject to one common pressure, the quantities that will pass in each split are in proportion to this formula:

$$\frac{1}{\sqrt{\frac{\left(\frac{1}{a}\right)^2 \times s}{a}}},$$

or finding p for an equal quantity passing in each split, the quantities in each split will be in proportion to $\frac{1}{\sqrt{p}}$.

44. The relative pressures or powers to pass the same quantity of air through aircourses of different areas and rubbing surfaces may be found by $\frac{s\left(\frac{1}{a}\right)^2}{a}$ or $s\left(\frac{1}{a}\right)^3$ which formulæ we have used in obtaining the figures contained in the third column of each of the tables on pages 284 and 285.

45. When the aircourses are of the same area and perimeter, and the pressure is the same, the quantities are in proportion to the reciprocal of the square root of the length $= \frac{1}{\sqrt{l}}$.

46. The water-gauge due to friction i 9 in. The downcast is 10 ft. in diameter and 70 fathoms deep, the upcast is 9

ft. diameter and 70 fathoms deep. The aircourses underground are as follows:

One	900	yards long	6 ft. × 5 ft.
"	800	"	6 ft. × 6 ft.
"	1,000	"	7 ft. × 5 ft.

Find the quantity of air passing, applying Mr. Atkinson's co-efficient of friction throughout—

.9 in. × 5.2 = 4.68 lbs. pressure.

In this case we proceed to find the pressure necessary for passing 40,000, which altogether amounts to 8.8561 lbs., then as $\sqrt{8.8561} : 40{,}000 :: \sqrt{4.68} = 29{,}077$, as worked out in the table below, the formula at the head of each column explains where necessary the manner of proceeding; it has been assumed that the splits are subject to one common pressure.

47. The next table is given by way of exercise for the student—the question being, What quantity of air will pass through the mine with a total pressure of 8 lbs. per square foot, the current being divided as specified, Nos. 1 and 2 being the shafts, 3, 4, 5, and 6 splits, subject to the same pressure? It is not necessary here to explain how the figures in the first seven columns of this table have been obtained, but those of column 8 are on the assumption that 40,000 ft. of air pass through each division (any other quantity might have been assumed); column 9 is the the reciprocal of the square root of the pressure given in column 8. In column 10, we give the quantities that pass in each division when the total is 40,000; of course the two shafts (1 and 2) pass the total quantity of 40,000, and the quantity in each division underground is in direct pro-

Divisions of the air currents.	a.	s.	Relative pressures $= \left(\frac{1}{a}\right)^2 \times s.$	Square root of relative pressures $= \frac{\sqrt{\left(\frac{1}{a}\right)^2 \times S'}}{a}$ or $\sqrt{S\left(\frac{1}{a}\right)^3}$	Reciprocal of the sq. root of relative pressures = relative quantities $= \frac{1}{\sqrt{\left(\frac{1}{a}\right)^2 \times s.}}$	Quantities in direct proportion to relative quantities.	p, for assumed quantity $= \frac{k s v^2}{a}$	p = in direct proport'n to figures in previous col.	$q = \sqrt{\frac{p a}{k s}}$
Downcast.	78.54	13194 72				40,000	.9456	.4997	29,077
Upcast. . .	63.6174	11875.284				40,000	1.6014	.8462	29,077
1st airc'rse	30	59,400	2.1999956	1.4832382	.674201	11,496	6.3091	.3341	8,357
2d airc'rse	36	57,600	1.2345332	1.1110999	.900009	15,346			11,156
3d airc'rse	35	72,000	1.679296	1.2958768	.771678	13 158			9,564
					2.345888	40,000	8.8561	4.68	29,077

No.	Size.	Length.	Perimeter.	s.	a.	q.	$p = \frac{ksv^2}{a}$	$\frac{1}{\sqrt{p}}$	q.	p.	p in proportion to col. 11, total being 8 lbs.	Actual quantity for the total pressure of 8 lbs.	u.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1	8×8	900	32	28,800	64	40,000			40,000	3.814	2.147	30,012	64,436
2	7×7	900	28	25,200	49	40,000			40,000	7.437	4.187	30,012	125,660
3	8×3	1,500	22	33,000	24	40,000	82.88188	.1098424	7,558			5,671	9,448
4	5×5	1,300	20	26,000	25	40,000	57.77408	.1315629	9,053	2.959	1.666	6,792	11,315
5	4×5	1,200	18	21,600	20	40,000	93.74400	.1032828	7,107			5,332	8,883
6	6×6	1,000	24	24,000	36	40,000	17.86005	.2366237	16,282			12,217	20,354
								.5813118	40,000	14.210	8.000	30,012	240,096

portion to the figures given in column 9. In column 11 it is seen that the total pressure required to pass 40,000 is 14.21 lbs., but as only 8 lbs. is the pressure in force, we proportion the figures in column 12 with those of 11, so that they amount to 8 lbs. and then we find if $\sqrt{14.21}$ give 40,000 that $\sqrt{8}$ will give 30,012, and that the quantities passing in each split 3, 4, 5, and 6 will be according to the figures given in column 13, and the total power (u) as per column 14, will be 240,096.

48. By way of exercise for the student it has been further assumed that another aircourse (No. 7) 5×5 and 1,300 ft. long be added to those enumerated in the previous paragraph, and that the power in force remains the same. With these conditions the quantity passing, it will be seen, is only increased from 30,012 to 30,744, as per table on this page.

No.	Size.	Length.	Perimeter.	s.	a.	$\frac{1}{\sqrt{\frac{(\frac{1}{a})^2 \times s.}{a}}}$	q.	p.	q.	p.	u.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1	8×8	900	32	28,800	64		30,012	2.147	30,744	2.2533	69,275
2	7×7	900	28	25,200	49		30,012	4.187	30,744	4.3933	135,068
3	8×3	1,500	22	33,000	24	.6473508	4,624		4,737		5,509
4	5×5	1,300	20	26,000	25	.7054475	5,539		5,674		6,599
5	4×5	1,200	18	21,600	20	.6085806	4,348	1.108	4,454	1.1630	5,180
6	6×6	1,000	24	24,000	36	1.3942729	9,962		10,205		11,868
7	5×5	1,300	20	26,000	25	.7054475	5,539		5,674		6,599
						4.0610993	30,012	7.442	30,744	7.8096	240,098

In this case we have proportioned the quantities in each split by the figures in column 7; and in taking 30,012 as the total quantity of air passing we find the pressure, as per column 9, to be 7,442; this multiplied by the quantity gives 223,349 units; then we find if $\sqrt[3]{223349}$ give 30,012 that the $\sqrt[3]{240096}$ gives 30,744, and the quantity in each split is proportioned again according to the figures in column 7. The pressure, p, in column 11 may be obtained by proportioning it with the figures in columns 8, 9, and 10, or by working out directly from the quantity in column 10 by the formula—$p = \frac{k s v^2}{a}$, and u in column 12 is obtained by multiplying the figures in columns 10 and 11 together; and it will be seen that the total units in this column amount to 240,098, which is correct within 2 units in the previous table.

49. Suppose a mine to have two splits of air only, one offering five times as much resistance as the other, and that the ventilating pressure required to circulate the air through the shafts and undivided airways is one-twelfth of the whole ventilating pressure. With a total quantity of 100,000 feet passing per minute, and putting the rubbing surface of the shafts at 10,000 and area at 100, then the figures in the table below will show the relative rubbing surfaces, areas, buantities, and pressures meeting these conditions.

Divisions of the air.	s.	a.	q.	p.
Shafts.....	10,000	100	100,000	2.17
Mine.....	1,151,912	100	30,902	23.87
	230,388	100	69,098	
				26.04

50. If the pressure remain the same as stated in previous paragraph, and there are three splits offering resistances in the ratio of 3, 2, 1, then the relative quantities, rubbing surfaces, areas, and pressures will be according to the following table:

Divisions of the air.	s.	a.	q.	p.
Shafts.....	10,000	100	148,869	4.81
Mine.....	691,150	100	37,623	21.23
	460,767	100	46,079	
	230,383	100	65,167	
				26.04

The examples given in this and the previous paragraph are to be found in another form at page 182 in the Transactions of the North of England Institute of Mining Engineers, Vol. VI.

51. If the downcast and upcast shafts of a colliery are each 180 fathoms deep and 12 ft. 5 in. diameter, and with one undivided aircourse in the mine having $a=36$ and $s=120{,}000$, the quantity of air circulating is 15,000 cubic feet per minute, what quantity will pass when there are 2, 3, 4, 5, and 6 equal splits, the pressure remaining the same? In the first place we find the total pressure required to pass 15,000 ft. of air with only one aircourse is 12.78954 lbs., then we find what the relative pressures are on 15,000 in the case of all the splits, as per column 4; the pressure in column 5 is then apportioned directly according to the figures in column 4; and from the pressure in column 5 we get the quantity in column 6 by the rule—$\sqrt{\frac{p}{k}\frac{a}{s}} \times a$ and u is got by multiplying p and q together.

Supposing it be required to know what quantity will pass with the power (u) remaining the same, we find by the table that this amounts to 191,843 units when the air is passing round the mine in one current, then by the table we see that with the same pressure there are 39,968 feet of air passing with two splits, and that the power (u) amounts to 511,172, then we say

As $\sqrt[3]{511172} : 39968 :: \sqrt[3]{191843} : 28666$, the quantity of air that will pass when

Divisions of the current.		a.	s.	Relative pressures on a quantity of 15,000$=\frac{k\,s\,v^2}{a}$	p.	q.	u.
No.	1.	2.	3.	4.	5.	6.	7.
1	Shafts....	121.087	84,240		.231669	15,000	3,475
	Mine.....	36	120,000		12.557871	15,000	188,368
					12.789540		191,843
2	Shafts....	121.087	84,240	.231669	1.644796	39,968	
	Mine.....	72	120,000	1.569734	11.144744	39,968	
				1.801403	12.789540		511,172
3	Shafts....	121.087	84,240	.231669	4.252363	64,265	
	Mine.....	108	120,000	.465106	8.537177	64,265	
				.696775	12.789540		821,920
4	Shafts....	121.087	84,240	.231669	6.924602	82,008	
	Mine.....	144	120,000	.196217	5.864938	82,008	
				.427886	12.789540		1,048,845
5	Shafts....	121.087	84,240	.231669	8.920971	93,082	
	Mine.....	180	120,000	.100463	3 868569	93,082	
				.332132	12.789540		1,190,476
6	Shafts....	121.087	84,240	.231669	10.223839	99,647	
	Mine.....	216	120,000	.058138	2.565701	99,647	
				.289807	12.789540		1,274,439

there are two equal splits, and the power remains the same, or we work out the results in the case of all the splits as follows:

$$\text{With 2 splits} = \frac{\sqrt[3]{191843} \times 39968}{\sqrt[3]{511172}} = 28666$$

$$\text{With 3 splits} = \frac{\sqrt[3]{191843} \times 64265}{\sqrt[3]{821920}} = 39347$$

$$\text{With 4 splits} = \frac{\sqrt[3]{191843} \times 82008}{\sqrt[3]{1048845}} = 46291$$

$$\text{With 5 splits} = \frac{\sqrt[3]{191843} \times 93082}{\sqrt[3]{1190476}} = 50370$$

$$\text{With 6 splits} = \frac{\sqrt[3]{191843} \times 99647}{\sqrt[3]{1274439}} = 52617$$

ASCENSIONAL VENTILATION.

52. By ascensional ventilation is meant the art of conducting the air underground so that it shall in the first place go directly to the lowest part of the workings and afterwards rise as it returns to the bottom of the upcast shaft. The intake generally being colder than the return, by this system return air is made to ascend and not descend. There is a loss of power in conducting return air downwards to the upcast, and this is a practice that should be avoided as much as possible.

53. The rules and tables referring to the friction of air and to the different quantities that will circulate with certain pressures, as given in the previous chapters, apply only to horizontal channels and not to dip and rise roads; for in practice it is found, whilst the quantities of air that will pass in different splits in the same horizontal plane preserve the same proportion whatever the ventilating pressure may be, such is not the case with dip and rise plits.

54. The reason of this is that there is a difference between the density of the intake and return air due to change of temperature, the mixture of watery vapor, the emission of gases, &c., and as the return air of any current is generally less dense than the intake (on account of the gases emitted being usually lighter than common air, &c.) there is mostly a natural influence at work in favor of the intake current passing to the dip, and returning by an ascending route, and against the air going first to the rise and returning by a descending road. Supposing a dip and rise split to be subject to one common ventilating pressure, in the case of the dip split there is to be added the pressure due to natural influences, in the case of the rise split the pressure due to natural influences is to be deducted from the general ventilating pressure, and thus it happens if there be a long split and a short one, both level, in order to pass equal quantities of air in each it will be necessary to put a regulator in the short one; and on reducing or increasing the ventilating pressure the quantities will still be equal, but if the long one is a dip split and the short one a level one, on reducing the total quantity of air the long split will get a greater proportion than originally. On the other hand, if the long split is a rise one and the short split a horizontal one, on reducing the total quantity of air the long split passes less and the short one more than the original share. This fact, so repeatedly proved in practice, clearly shows the value of the principle of ascensional ventilation and the mistake in carrying return air down the bank. If, however, the returns were charged with gases heavier than common air to such an extent as to render them more dense than the intake air, the opposite results would take place on reducing or increasing the general ventilating pressure in the case of dip and rise splits. This, however, is an exceptional case, for, as said before, the return air of mines is generally less dense in consequence of being usually higher in temperature, and impregnated with the lighter gases; and it is therefore, speaking generally, wrong in principle to bring return air down the hill. The descent of return air in places which give off fire damp has been, and is likely to be, the cause of serious explosions.

55. In colleries giving off fire damp it is well to have the return aircourse on the upper side of the workings; by this means the gas will be naturally drained away by gravity from the goaves or where workmen are employed.

56. If the ascensional principle of ventilation be carried out, the exudation of carburetted hydrogen in a mine will have the effect of increasing the ventilation. The light specific gravity of the fire

damp, as compared with that of air, will be equal to an additional ventilating pressure. This principle appears to be well understood in Belgium and in Westphalia, particularly so in the last-mentioned coalfield, where, according to the experience of the writer, it is the prevailing system.

57. In furnace ventilation the best current of air is produced by having the furnace placed on the dip side of the underground workings, because in that case a longer motive column or ventilating pressure is obtained; but in steeplying seams the advantage derived by the natural ascendancy of warm air and light gas is not only lost, but an additional pressure equivalent to this advantage is required to bring the light air down to the bottom of the upcast. Hence, ventilating fans made to exhaust the air from a shaft on the rise side of the workings are both in point of economy and safety better for ventilating steep seams than furnaces placed on the dip side.

58. If we suppose the rise workings to reach the vertical height of 50 fathoms, and the temperature of the intake be 55 degs. and return 85 degs., there will be a natural pressure due to temperature alone of 1 lb. per square foot,or one-fifth of an inch of water gauge in favor of mechanical ventilation with upcast shaft at the rise of the workings, and against furnace ventilation with the upcast at the dip, in addition to the extra resistance consequent on the increased length of aircourse and upcast. In order to make this plain to the student, we take from the table of the weight of air given under paragraph 6 the weight of a foot at 55 degs.=.0773515, and multiply this by 300=23.20545, and deduct the weight at 85 degs.=.0730858 multiplied by 300=21.192574, which gives a difference of 1.01 lb.

59. The average temperature of a furnace upcast may generally be taken at 100 degs. (at least) more than that of the mine, and consequently the increased pressure obtained at the bottom of the upcast by this increased length of heated air column will overcome any local pressure in the mine and compel the air to travel down-hill from the rise workings to the furnace, but this will be at the expense of additional fuel.

60. It has been stated that the gases emitted from mines are generally such as to render the return air lighter than the intake. This, however, depends on the specific gravity of the gas. The table following shows the specific gravity of the various gases met with in mines and the relative altitude they usually assume:

	S.G.
Hydrogen	0.069
Carburetted hydrogen	0.550
Aqueous vapor	0.620
Nitrogen and Miasma	0.976
Olefiant	0.980
Air	1.000
Oxygen	1.100
Sulphuretted hydrogen	1.190
Carbonic acid	1.520
Sulphurous acid	2.120

Those gases which are lighter than air have an influence in favor of the ascensional principle of ventilation; those which are heavier will act prejudicially to it.

VELOCITY OF AIR.

A velocity of 6 in. per second or 30 ft. per minute is enough to deflect the flame of a candle, and 3 ft. per second is sufficient to remove and render harmless the ordinary discharges of fire damp. A return aircourse 7 ft. square passing 30,000 cubic feet of air per minute gives a velocity of about 10 ft. per second. In many of the furnace pits of the North of England the air travels at a velocity as high as 30 ft. per second. It is not always practicable, however desirable, to reduce the velocity in returns or upcast shafts to a minimum, but it is very important that the air in the working parts of a mine should not travel at less than say 2 ft. per second, or more than 7 ft. The medium between these would be the best average velocity; but a very much greater velocity than this is attained in some collieries.

62. There are several reasons why air should not travel at a high velocity. One is because, if it be very much surcharged with fire damp, enough to render it inflammable, there is a danger of some of the commonly used lamps exploding. Another reason is that the pressure required to overcome the friction is according to the square of the velocity, and the power according to its cube. The following table shows the relative press-

ures and powers required to move the air through the same aircourse at the velocities stated:

Velocity in ft. per second.	Relative pressures.	Relative powers.
3	1.	1.
4	1.77	2.37
5	2.77	4.63
6	4.	8.
7	5.44	12.70
8	7.11	18.96
9	9.	27.
10	11.11	37.03
12	16.	64.
14	21.77	101.63
16	28.44	151.70

Thus we see there is 16 times the pressure and 64 times the power required to pass the air through the same channel, at a velocity of 12 ft. per second that is necessary at 3 ft. per second. Thirdly, when air travels too rapidly it is disagreeable to the workmen and all who have to move in it; and it is difficult to prevent the light from being blown out.

63. Each split should have a current of 8,000 or 10,000 cubic feet per minute and the latter quantity at a velocity of 5 ft. per second would require an area of 33 square feet.

An inflammable mixture of pit gas and air, moving at the rate of 8 ft. per second will explode most of the ordinary safety (?) lamps.

THE CO-EFFICIENT OF FRICTION.

64. Throughout this treatise we have used the co-efficient of Mr. Atkinson, namely, .0000000217 lb. for each foot of rubbing surface, and a velocity of 1 ft. per minute. From this we find that $v=6788\sqrt{\frac{pa}{s}}$, because $\sqrt{\frac{1}{.0000000217}}=6788$.

65. Mr. D. K. Clark, in his most excellent book, *Rules, Tables and Data for Mechanical Engineers*, gives the following formula for the "flow of air through passages of any form of section" (substituting the notation used throughout these papers it is):

$$v=796\sqrt{\frac{wa}{s}}$$

and to bring this into the same terms as above:

$$\frac{796\times 60}{\sqrt{5.2}}=20{,}944,$$

therefore:

$$v=20{,}944\sqrt{\frac{pa}{s}}$$

66. M. Devillez, in his *Ventilation des Mines*, uses a co-efficient which is equal to .00000000951 lb. for each foot of rubbing surface and a velocity of 1 ft. per minute, now as:

$$\sqrt{\frac{1}{.00000000951}}=10{,}253\ v=10{,}253\sqrt{\frac{pa}{s}}$$

67. Recapitulating, we see that the velocity is found according to these three authorities as below:

Per Atkinson, $v=6{,}788\sqrt{\frac{pa}{s}}$

Per Devillez, $v=10{,}253\sqrt{\frac{pa}{s}}$

Per Clark, $v=20{,}944\sqrt{\frac{pa}{s}}$

68. The writer is inclined to think that Mr. Clark's formula is deduced from experiments with passages having smoother sides than those of underground roads generally, and consequently the friction is not so great; he has confidence in the result obtained by M. Devillez, but thinks until further experiments have been made it would be sufficiently near, as an average for underground passages, to use $10{,}000\sqrt{\frac{pa}{s}}$. This would be equal to .00000001 pound per square foot of rubbing surface, or $\frac{1}{100{,}000{,}000}$ for a velocity of one foot per minute, or .01 lb. or $\frac{1}{100}$ for a velocity of 1,000 ft. per minute, and these are factors that could be both easily remembered and used in calculation.

NOTE.

69. In the preceding pages calculations have been gone into to show the quantities of air that will circulate under certain conditions; it is necessary to state that these conditions never exist practically; for example, "equal splitting," as has

been explained under paragraph 31, cannot very well exist in a practical sense; then again in considering "unequal splitting," it has been assumed that the splits are all subject to one pressure; this can only be the case when all the splits divide from the main current at one point, and reunite again in the return at one point, which will not be found to be the case practically. It has already been pointed out in the earlier pages that one of the conditions—assumed to exist — is wanting in the case of dip and rise splits. Another condition affecting the consideration of the quantities that will pass with various powers or pressures is the coefficient of friction; in the calculations it has been assumed that one coefficient applies throughout the whole ramifications of the mine, from the entrance of the air at the mouth of the downcast till it escapes at the top of the upcast; but from experiment it has been found that the co-efficient varies with the nature of the rubbing surface; that in an arched tunnel or brick-lined shaft, for example, it is not nearly so much as for the ordinary channels of a mine. It has likewise been assumed that all the air which enters the mine passes completely through it, but this is not the case practically; air escapes at doors, stoppings, crossings, brattice, and through goaves, &c., and this to a very large extent in some collieries.

70. The amount of this fugitive air, if it may be so called, is not always a criterion of the ability displayed in carrying out the ventilation; in collieries having good means of producing air, and with limited workings, it is more permissible than in extensive collieries which require all the air in-bye that can be obtained; in such cases as the latter care must be taken to prevent the escape of air by taking the short route to the return, instead of passing through the working places.

71. All open places in a coal mine, whether in work or not, should have air passed through them, and in no case should old workings be shut up with air-tight stoppings; such a practice is very likely to lead to some casualty through places of this kind becoming dangerous magazines of gas.

72. It is hoped the calculations that have been gone into may be of some assistance to students in undertanding the question. The principal matter of this essay was worked out some twelve months ago, when the writer intended to consider the subject further; since then, however, his engagements have prevented him from devoting the necessary time to it, and for this reason certain experiments on the subject cannot at present be utilized.

ON THE ECONOMICAL USE OF GAS ENGINES FOR THE PRODUCTION OF ELECTRICITY.*

From "Nature."

The lecturer pointed out, that as long as the chief practical use of electricity was in telegraphy it was the quickness of action, rather than the ability to transmit large amounts of power to a distance, that formed the chief feature in the employment of electricity; but that in this exhibition the numerous practical examples of the electric transmission of power, rather than the electric transmission of signals, formed without doubt the leading feature.

Much had been heard about the dynamo-electric machines which generate the electric current; but while electricians were engaged in considering the differences between the various kinds of these machines and the improvements that can be effected in them, the mechanical engineer should give his careful attention to the possible improvements that can be made in the engines that drive the electric generators.

As long as the lighting of our large cities was performed by gas the cheap manufacture of illuminating gas was the important question, but now that electric lighting bids fair to displace other systems the question that has special interest is, not the extraction of illuminating gas from coal, but the employ-

* Abstract of a lecture delivered in French in the Salle du Congres, at the Electrical Exhibition, Paris, by Prof. W. E. Ayrton, F.R.S.

ment of the store of energy in the latter to set in rapid rotation dynamo-electric machines for producing the electric current used in lighting.

At present steam engines are chiefly used to drive the dynamo-machines, but even with the best engines and boilers it is well known that the fuel consumption is excessive compared with the actual work done. So good an authority as Sir William Armstrong has recently said that with a good condensing engine only one-tenth of the whole heat energy of the fuel is realized in useful work, and this is no exaggeration of facts. What therefore must be said of a small engine and boiler of the ordinary type? The main reason why the efficiency of even the best steam engines is so low is because in an ordinary engine steam can only be used at a comparatively low temperature; for it can be proved that, with the temperatures which can be used in condensing engines, the efficiency of even an imaginary perfect engine, without friction and loss of heat, cannot exceed $\frac{2}{10}$, or only double the efficiency of a good modern steam engine; that is to say that a good engine of large size uses only $\frac{1}{10}$ of the total heat, and that it is not possible to use more than $\frac{2}{10}$ with an engine of perfect mechanism.

It may be assumed that in large compound marine engines the fuel consumption is about 2 lbs. per indicated horse power, but it cannot yet be said that engines of this class and of very high power will be used in central stations for electrical purposes; at any rate it must be remembered that besides other considerations there is a great objection to the use of a single very large engine to electrically light a district, for the accidental stoppage of this engine would plunge the whole neighborhood into darkness.

Engines and boilers of the portable type are those generally used now for electrical purposes, and in a competition in England of several of the best engines of this class the fuel consumption was about 4 lbs. per indicated horse power per hour; but in daily practical work it may be assumed that 6 to 7 lbs. more nearly represent their usual fuel consumption. This gives an efficiency of only about $\frac{1}{30}$.

With a hot-air engine there is this great disadvantage, that it is extremely difficult to prevent the lubricants from being burnt and the air vessel being injured by heat, since the latter vessel must be kept as hot or hotter than the air, because the temperature of the air is raised by an *external* fire. The only other motor suitable for electrical purposes (apart from machines driven by water or wind power) is the gas engine. In the latter, the power is obtained by the admission of an explosive mixture of gas and air into the cylinder, and the piston is driven by the explosion produced on the ignition of this mixture.

Now, there is this great difference between a hot-air engine and a gas engine, that in the latter the high temperature arising from the explosion is produced *inside* the cylinder, and not outside; so that, although the gas at the moment after explosion is extremely hot, the cylinder, piston, and lubricant may be kept cool by an external stream of water, which is of course impossible in a hot-air engine where the air is heated from the outside. Again, the very high temperature developed in the cylinder after the explosion has taken place, is rapidly reduced by the piston doing work before there is time for the gas to give up much of its heat to the cylinder and piston. Steam, however, can only be used at a very high temperature, provided the apparatus is made exceedingly strong.

With the present temperatures employed, the theoretical efficiency of a gas engine might be raised from 56 to 75 per cent., if loss of heat by conduction, radiation, and convection, as well as friction, could be prevented; while in a condensing steam engine the greatest efficiency that could be obtained with the present temperatures employed could never exceed about 20 per cent.

It was thus shown that practically a gas engine admits of being worked with much greater *efficiency* than either a steam engine or a hot-air engine—that is to say, the percentage of heat the former turns into mechanical work is much greater than with the latter two. It was, however, necessary to consider the *economy* of working, which depends on the relative price of the fuel employed, and other items of working cost. Comparative estimates were therefore given of the working cost of a steam

engine of a portable type and of an Otto gas engine, both indicating 30 horse power, for 300 days of nine hours each (the horse power about necessary to keep alive the 400 Swan incandescent lamps used to illuminate the Salle du Congres during this lecture). The cost of the coal gas was taken at three shillings per 1,000 cubic feet (or about 13½ centimes per cubic meter, only about half the actual price in Paris), and it was thus seen that, in spite of the very great relative efficiency of the gas engine, the cost of working with ordinary coal gas is greater than in the case of the steam engine. Ordinary coal gas, however, has been prepared for producing not heat, but light, and has therefore been elaborately purified at a considerable cost, so that when used in a gas engine it is used for a purpose quite different from that for which it was intended.

A gas engine burning illuminating gas is, in fact, in the same position as was a few years ago an electromotor, or machine for converting electric energy into mechanical power. An electromotor is an extremely efficient machine, but the fuel burnt to produce the electricity was, until quite recently, zinc, and consequently was far too expensive to allow the use of electromotors to be commercially successful. So, in the same way, if it is attempted to work gas engines by burning illuminating gas at even 13½ centimes the cubic meter, or half the actual price of the ordinary gas in Paris, they cannot even be worked as economically as steam engines, in spite of their superior efficiency and of the much smaller cost for superintendence. But if it be possible to manufacture for their use a cheap heating gas in the same way as it is now possible to produce electric energy economically by burning coal, which is a much cheaper fuel than zinc, then the result, as you will see, becomes just the reverse, and small gas engines driven with such gas not only greatly surpass in economy steam engines of the same size, but produce energy at a cheaper rate per horse power than the largest steam engines ever made.

The lecturer then described what had been done by Dr. Siemens and others who have made a heating gas for furnace work by means of passing air only, or air with a small admixture of steam, through a mass of burning fuel. Such gas, however, contains too much nitrogen (60 to 70 per cent.) to be suitable for gas engines and other purposes requiring it to be used in small quantities, and the plant is large and costly. Reference was then made to what had been done by Mr. Dowson of London, who had perfected a gas-generating apparatus, into which he passes steam at pressure with a certain portion of air. This he effects by an arrangement similar to a steam-engine injector or a jet pump. The air thus drawn into the generator serves to keep the column of fuel through which it passes at a high temperature, without an exterior fire, so that the decomposition of the steam and the other chemical reactions take place without interruption. The working of the generator is thus regular, and the gas is produced without fluctuations in quality.

Experiments were made with a eudiometer, in which were three volumes of the Dowson gas and one of oxygen, and on exploding the mixture, 36 per cent. of the total disappeared. This corresponded with the following composition of the Dowson gas, viz. hydrogen, 20 per cent.; carbon monoxide, 30 per cent.; carbon dioxide, 3 per cent.; and nitrogen, 47 per cent. by volume. It was also shown that this gas burns without smoke or any deposit of soot on a piece of porcelain, whether placed above or in the middle of the flame.

About 50 per cent. of this gas is combustible, and its calorific power, or the number of heat units produced by the combustion of a cubic meter, is 1,558,358. Its calorific intensity is 2,268° C. To compare it with ordinary coal gas we may take the calorific power of a cubic meter of the latter to be 5,590,399, and its calorific intensity as 2,554° C.

In the Otto gas engines a large proportion of air is mixed with the coal gas, so that the effect of the explosion may continue during the stroke of the piston by the air taking up some of the heat produced; and as the Dowson gas requires less air for its combustion, it is found that in the same cylinder there is not more nitrogen and unused oxygen in the charge of Dowson gas with its mixture of air, than with coal gas and the

quantity of air which is given to the latter. That is to say, that the same power can be developed in the engine with coal gas or Dowson gas if the supply of gas and air be exactly proportioned.

The comparative explosive force of the two gases calculated in the usual way is as 3.4 : 1, *i.e.* coal gas has 3.4 times more energy than the Dowson gas. But because the combustion of carbon monoxide proceeds more slowly than that of carburetted hydrogen gases, and because the diluents present in the cylinder affect the weaker gases more than the coal gas, in practice, with an Otto engine five volumes of the Dowson gas are used for one volume of coal gas.

A table was given showing all the working expenses of an Otto gas engine, indicating 30 horse power, and driven by the Dowson gas for 300 days of nine hours each, so that these expenses might be compared with those given for the steam engine and the gas engine worked with coal gas. These figues showed that a gas engine, worked with Dowson gas, cost about 45½ per cent. less than when worked with coal gas at 3s. per 1,000 cubic feet, and about 47½ per cent. less than a steam engine of the portable type, after allowing in each case for repairs and depreciations, and interest on capital outlay. The most striking feature, however, was that with a steam engine consuming 6 lbs. of coal per indicated horse power per hour, and without adding any allowance for fuel used in getting up steam, and after work is done 217 tons of coal are required to give the same power as 39 tons of coal converted into gas by the Dowson process. This represents a saving of about 88 per cent. in the weight of fuel.

Another practical consideration was that the quantity of the Dowson gas required to give the equivalent of 1,000 cubic feet of coal gas was only 24 to 27 per cent. of the weight of the coal necessary for the latter. A further point of great interest is that a series of trials made with 3½ horse power (nominal) Otto engines driven by the Dowson gas, have proved that 1 *horse power (indicated) is obtained with a consumption of gas derived from* 1.46 *lbs. of coal*, after allowing for the gas burnt in the manufacture of the gas, as well as ten per cent for impurities and waste of the coal. With gas engines of larger power the loss due to friction is proportionally less, and the consumption of gas per indicated horse power is less, thus with a 16 horse power (nominal) engine which can indicate up to about 40 horse power, the Dowson gas required would be about 90 cubic feet per indicated horse power per hour, and this would give a consumption of coal of *only* 1.2 *indicated horse power per hour.*

Moreover, with a cheap heating gas not only can a saving in the motive power be effected for electric lighting, but this gas can also be used for domestic and industrial purposes, such as cooking and heating. It burns without smoke, so that when it is used in districts where there are many factories, or where much coal is consumed, not only will a great saving be effected, but in addition there will be freedom from a dark depressing atmosphere—the presence of which, the lecturer remarked, was the bane of London, and the absence of which formed the greatest charm of Paris.

THE NEW FAURE ACCUMULATOR.—After trying lead plates covered with minium and sheathed in flannel, then rolled into a spiral form for the Faure accumulator, recourse was had to square plates standing side by side. M. Emile Reynier, however, electrician to the Force et Lumiere Company, has modified the battery by returning to the original shape of a spiral roll for the plates, and sheathing them in a sort of linen serge instead of flannel, after they have received their coat of minium. He also encloses the plates in a glass vessel instead of a wooden trough, principally because the electrician can more easily see if there is any discharge of gas bubbles from the plates. In charging, the appearance of these bubbles, if the cell is a good one, indicates that the supply of current ought to be suspended, because the cell is full. Should the bubbles appear before the charging is complete the cell is considered faulty. The reason of this is that the oxygen liberated on the electropositive plate ought to be entirely used in oxidizing the minium, and it is only when that oxidation is complete that the gas should rise from the plate.

THE COMBINATION SYSTEM OF STEAM HEATING FOR TOWNS AND VILLAGES.

By CAPT. DOUGLAS GALTON, C.B., Hon. D.C.L., F.R.S., &c., &c.

From the "Journal of the Society of Arts."

THE vast increase in the size of the metropolis, and of other towns in the United Kingdom, has brought into prominence the question of how to maintain a pure atmosphere over such extensive congregations of houses. One of the most prominent causes of impurity in a town air is smoke and soot.

Where vapor of water or fog prevails, it has been shown that when particles of coal tar are floating in the atmoshere, they attach themselves to the watery vesicles of fog or cloud, and coat them with an oily film, which retards the evaporation of the water. These conditions operate to give a greater degree of permanence to a cloud thus composed of watery vesicles and smoke, than clouds consisting of water vapor alone posseses.

The exhibition which has been opened at South Kensington exemplifies very clearly that this cause of impurity is, to a large extent, under our own control, and that, with more careful and scientific appliances, we might easily reduce the quantity of visible impurity which our chimnies vomit into the atmosphere.

The various apparatus which are exhibited may be divided into those, on the one hand, which deal with the method of consuming coal in a smokeless manner, in each separate house; and, on the other hand, those which make use of gas, and thus require some central establishment to create their smokeless fuel, and transmit it to the several houses, to be there applied to heating and cooking purposes.

The Exhibition does not, however, contain any description of a method of heating which was proposed a few years ago, and has actually been adopted in the United States of America. This provides for consuming the fuel at a central source of supply, and sending thence the heat itself to supply the several houses in connection with it, and the system thus dispenses with the necessity for consuming the fuel in each individual house. This system is called the Combination System of Steam-heating for Cities and Villages, and was devised by Mr. Holley.

The system of heating houses by steam, instead of by hot water, has obtained a large development in the United States.

In the ordinary steam-heating apparatus which is in general use in houses in the United States, and in which the steam is under pressure, the flow pipe should be carried in as direct a line as possible from the boiler to the highest point: all the coils for heating should be placed on the return pipe, which should be laid in a uniformly descending line back to the boiler, so arranged as to prevent the lodgment of any condensed water on its way there, it being a source of economy in steam heating that the condensed water should flow back to the boiler.

The use of steam for heating pipes for warming purposes possesses certain advantages, and when the object is to warm air, the higher the temperature of the pipes the greater is the comparative effect. When compared with pipes heated by hot water under ordinary conditions, steam-heated pipes also possess the advantage that when a high temperature is obtained in the pipes heated by steam, there results the consequent radiation of a large proportion of heat to the walls of a room.

Steam heating possesses some disadvantages. The steam frequently makes unpleasant noises, if air or water lodges in the pipes. The heat given out is very great, and becomes often oppressive. Under the ordinary arrangements for steam heating, the temperature of the pipes cannot be regulated as with hot water. This latter objection is met to some extent by separting the coils into parts, which can be put in operation consecutively.

Mr. Holley, in the system of combined steam heating, which is about to be described, has advised an arrangement of pipes, which he terms the atmospheric

radiator, to enable the temperature of the pipes to be regulated. In the combination system of steam heating, the steam, when once it enters the house, becomes the property of the occupier of the house, and the condensed water does not return to the boiler: the steam for the radiators is taken out of the flow-pipe through a valve, regulated by a thermostat, so arranged as to open and close the valves, admitting steam to the radiators; this thermostat may be adjusted to operate within ten degrees of temperature, so that the heat of a room may be automatically maintained at about the temperature desired. The steam is admitted at the top of the radiator, through the valves, in such quantity as is desired, the bottom being open; the amount of steam admitted is determined by the temperature which it is desired to maintain, and by the amount of radiating surface. Thus, if a moderate temperature is required, a little steam will be admitted to the upper portion of the tubes. The heat from this small quantity of steam will be rapidly diffused by the surface of the radiator through the air of the room, and the inlet valve can be so adjusted as to control the amount of steam admitted; by this means the temperature of the room may be maintained at any required degree. The advantages claimed for these radiators are economy of manufacture, and ease of graduating to all weather; they may be made of tin, or galvanized iron, of any required height and design. The steam and water of condensation give off all their heat, and there being no valve in the return pipe, and no pressure, there is no cracking and spluttering noise, as in pressure radiators.

The steam, after it has passed into these radiators, cools down and becomes water, and passes entirely away from the steam pipes, to be applied to such other purposes as the house owner desires, as will presently be explained.

Thus, in the ordinary system of heating by steam, in use in houses in the United States, the steam circulates continually from the boiler to the radiator, and returns as condensed water to the boiler; whereas, in the Combination system, the steam does not circulate back to the boiler, but, after it has passed into the house, passes away as water. That is to say, the steam in this system is taken from a steam main, laid through the streets, just as gas or water is taken from a main, and the heat from the steam is consumed in the houses in such a manner as owner of the house thinks fit.

The following is the general arrangement of the system:—The boilers are placed in a convenient central situation. The results given by Mr. Holley of a series of experiments on several boilers in use by him, show that, at Lockport, he evaporated, on an average, from 6 lbs. to 9.5 lbs. of water per pound of coal; this, of course, is a matter greatly depending on the quality of the fuel. Mr. Holley speaks in high terms of the Murphy smokeless furnaces, with regard to which he says:—"The perfect combustion and consequent total abolition of smoke from bituminous coal, and relative economy in the production of steam, are not the only points of superiority, as its cleanliness, ease of management and saving of labor, are almost equally important. The stocking of the boiler resolves itself merely into dumping the coal from cars into the bin above the fire box in front of the boiler, and occasionally pulling it towards the feed. A little engine carries it into the coking chamber, dumps it at the proper time on the grate bars, and, by means of levers moving the shake bars to and fro, slowly clears the bars of ashes. The doors are never opened, and one attendant, without a fireman's skill, will manage a battery of six boilers worked by the same power." This arrangement of furnace appears to have some resemblance to the McDougall furnace in the Smoke Abatement Exhibition.

From the boiler the steam passes into the main pipes and lateral or branch pipes. These have been made of lap-welded wrought-iron steam pipes. They vary in size according to the duty they have to perform. The largest yet laid is stated to be 12 inches diameter. The maximum steam pressure would be 100 pounds per square inch; but the pipes are made to resist strains many times in excess of the maximum pressure to which they can be subjected, and they are carefully tested.

It is essential to guard against the condensation, for, unless steam can be transmitted to considerable distances without too great loss by condensation, all devices

to use it in buildings, however ingenious, would, of course, be useless. Condensation being caused by the radiation of heat from the pipes, the object is to arrest the radiation, that is, to keep in the heat by inclosing the pipes in the best non conducting material that is attainable and cheap enough. In order to effect this, the pipe is wound about, first, with asbestos, followed by hair felting, porous paper, manilla paper, finally, thin strips of wood laid on lengthwise, and the whole fastened together by a copper wire wound spirally over all. This is thrust into a wooden log, bored to leave an intervening air chamber between the pipe and the wood, and of sufficient size to leave from three to five inches of wood covering. The elasticity of the wrappings permits the free expansion and contraction of the pipe, irrespective of the wood log, which is securely anchored and made immovable. The whole is placed in a trench a short distance below the surface, without regard to frost. At the bottom of the trench is laid an earthen tile drain, to carry off any earth moisture; and in order further to insure the continuous dryness of the wood log enclosing the pipe, if desired, 1½-inch plank is fastened around the log, leaving an air space, and the whole is daubed with coal tar, and covered with earth.

Pipes prepared in the manner described have been tested, and it is stated that these tests show that condensation can be reduced to a point that renders the general transmission of steam not only practicable, but profitable; that is to say, that the loss of heat by condensation is under 2¼ per cent. The only actual experiment of which particulars are given, does not furnish so high a result; this experiment was on 1,600 ft. of three-inch pipe, laid on a descending grade of about 1 in 250, the lower end trapped for water, the steam pressure constantly maintained at 20 pounds at both ends, during 12 hours, and the water of condensation, carefully weighed, amounting to 82 pounds per hour, *i. e.*, about .068 pounds of water per square foot of surface of pipe; that is, 66 units of heat per square foot per hour, or 52 units per foot run. The loss of heat from uncovered steam pipes, with steam of 40 lbs. to 60 lbs. pressure, may be assumed, probably, at something between 320 and 380 units of heat per square foot of surface, partly dependent upon the outside temperature. The Holley boilers in this experiment are stated to have evaporated nine pounds of water per pound of coal. Therefore the extra coal required to keep up the loss from condensation amounted to nine pounds of coal, or at the rate of 30 pounds of coal per hour per mile of three-inch pipe. The actual amount of condensation in large pipes is greater than in small pipes, but the relative per-centage per square foot of surface less than in small pipes. It is stated that from experiments and practice, verified in fifteen cities, the most economical pressure to be maintained in the mains, is from 40 to 60 pounds, although in some cities 70 pounds have been used. Experience with large mains is yet limited. The experience of Detroit demonstrates the fact that 60 pounds pressure could be maintained in four miles of 10-inch and 6-inch pipe, against the drafts for power and heat along the line.

In order to counteract the difficulty arising from the expansion and contraction of the pipes, which are subject to extremes of temperature, varying from, say 39° Fahrenheit, and the temperature of steam at, say 60 lbs. pressure, *i, e.*, 307° Fahrenheit, a junction and service box are used. These are placed at convenient intervals along the line, of 100 to 200 feet. The arriving pipe from the boilers is inserted in the service box by means of a nickleplated extension, or telescopic joint, made steam tight by passing through a stuffing box. The departing pipe is immovably attached to the box, so that one end of each 100 feet of pipe is fast, and the other movable—affording free play to the expansion and contraction.

All service-pipes are taken from the junction-box, which is securely bolted to the masonry and anchored to the pipes. The bottom of the box, being placed lower than the pipes, all water of condensation is carried forward and deposited in it; the arrangements for the escape of the condensed water from the steam pipes will be described presently.

At each point of consumption there is a cut-off, under the control of the consumers. The supply pipes from the mains to the houses are 1½ inches in dia-

meter, and within each house ¾-inch pipes are used. In addition to the cut-off tap from the main, under the control of the consumer, there is a pressure valve or regulator, by means of which the pressure of steam is reduced, and the supply of the building regulated automatically. This is accompanied by two diaphragms of rubber packing, acted upon by weighted levers, and moving two side-valves. The first valve is weighted to 10 lbs., and the second to 5 lbs., or 2 lbs., if required.

When the steam arrives at the first valve of the regulator, it is under a pressure of 60 lbs.; on passing through the first reducing valve, the pressure is reduced to 10 lbs.; it is then passed through a second reducing valve, and the pressure lowered to 5 or 3 lbs.; thence it passes at this uniform pressure through a meter placed above the regulator, for measuring the amount of steam which passes into each house. Unfortunately, I am not in possession of a drawing, or description of these regulating valves or of this meter, sufficiently clear to enable me to explain their action in detail.

The distribution of heat in the apartments is by means of the radiators before mentioned, which are of the ordinary shape, consisting of inch-pipes about 32 inches long, placed vertically, either in a circle or a double row, and connected together top and bottom. The action of these, in enabling the heat to be regulated, has already been explained. The steam, in passing these radiators, becomes condensed into water at 212°. The heat then remaining and the water may both be utilized. In order to effect this, it is conducted in protected pipes, from all parts of the building where steam has been used, back into the basement, through a specially devised trap. Here it may be used as warm water, or it may be used for warming fresh air; in this case it is passed into coils of pipe set in a brick chamber; into this chamber cold air is admitted from outside of the building, as in the air-furnace, and coming in contact wth the coils of pipes containing the hot water, abstracts the remaining heat, and passes up, through the registers into the rooms above, as warm, pure air, while the water, now cold, passes into the tank for future use, if required.

Holley's steam-trap, by which the water of condensation is permitted to escape from the steam pipes, whilst the steam is retained, is a most simple device. The trap is a vertical cylinder, which can be placed either in connection with the junction and service boxes in the mains or in the houses at the bottom of the return pipe from the radiator. In this cylinder a bucket is suspended by means of a lever. This lever is connected with a valve, which leads into an escape-pipe, carried from the bottom of the cylinder. When the end of the lever to which the bucket is attached is in its normal position, the valve is closed; but when this end is raised, the valve is opened. When the condensed water from the steam rises in the cylinder, it causes the bucket to rise and to push up the end of the lever; this opens the valve, and the water below escapes. The bucket falls again, when the water sinks in the cylinder, and closes the valve before the level of the water is sufficiently reduced to allow the steam to follow.

The heat supplied through the agency of steam can, moreover, be utilized for warming water for domestic use. This may be effected, either by passing a coiled steam pipe through a cistern of water, or by turning the steam direct from the steam pipe into a jug or bucket of water, through an apparatus attached to a flexible tube, and resembling the rose of a watering pot, but with very minute holes to prevent noise. The heat of the steam at a low pressure may also be utilized for cooking, stewing, boiling; and vegetables can be cooked with the steam at the pressure at which it is supplied for warming purposes. But to *brown* meats, *broil* beefsteak, and form the crust of bread, requires a temperature of not less than 300° to 420°, being an amount due to a steam pressure varying from 60 pounds to 350 pounds.

Steam ovens have have been long in use. Mr. Loftus Perkins brought a steam oven for baking bread to the notice of the Government during the Crimean War, and cooking by this means has attained considerable development. But for this, steam at a high pressure is necessary.

Mr. Holley states that a stove, invented by Dr. Silsby, superheats the steam for purposes of baking, broiling and roast-

ing. This stove is made of iron, encased in wood, with single and double ovens, and of various styles. The ovens and top are used precisely as in other stoves. The stewing, boiling and cooking of vegetables is conducted with the steam at low pressure; but when it is desired to bake, broil, or roast, or heat flat irons, it is only necessary to cut off the communication with the steam-supply pipe, leaving the steam in the oven, and to light an argand gas-burner, or, in the absence of gas, a gasoline or coal oil lamp; and in a short time the steam that already surrounds the ovens at 212° becomes superheated to the temperature desired, as indicated by a thermometer, and the cooking is done in the usual manner as in other stoves and ranges. In order to leave nothing to the ignorant or careless discretion of an attendant, an automatic thermostat is arranged to control and regulate the temperature. Superheating must be resorted to for the purposes named; other culinary and domestic processes can be conducted with the low-pressure steam.

Mr. Holley states that the tests to which this stove has been subjected show that it performs the duty of the best cooking stoves in use, without inconvenience and annoyance, with satisfactory results, and in a short time. For example, the average time for roasting meats by this arrangement of superheated steam is stated to be 12 minutes to the pound. Bakers require 30 to 40 minutes to bake 1¼-pound loaves in ordinary ovens; the superheater bakes 1¼-pound loaves with greater uniformity and certainty. A 2-pound steak is broiled in 8 minutes; mutton chops in 4 minutes; oysters are broiled in 4 minutes; a 12 pound turkey required 2 hours to roast; 8 pounds of roast beef, 1 hour; 1 gallon of coffee, from cold water, 8 minutes; light bisquit or buns, 8 minutes; potatoes were baked in 28 minutes.

I have not seen this cooking stove; but if it as satisfactory as the description implies, it would seem that if combined steam heating were introduced into houses, the occupier of a house would be enabled to dispense entirely with fires in the house, and thus be relieved from all the trouble, difficulty, expense, and dust and dirt incidental to their use.

The cost of the fittings in a house fall, of course, on the consumer. The cost at Lockport is stated as follows:—In a moderately-sized eight-roomed house, the expenses have amounted to about 150 dollars, or a trifle over £30; and in a large house, with more expensive fittings, 500 dollars, or about £100. But in applying this system to houses, it may be observed that the manner of applying the heat may be varied according to circumstances. If desired, fresh air may be heated by means of steam pipes in the basement, and conveyed by ducts in the walls to the various rooms, or radiators may be devised to warm the walls of the rooms, so that the unpleasant effect of cold walls and warm air in a room would be obviated. Coils of pipes might be arranged so as to heat flues, or the steam might be applied to work a fan for the extraction of air, and by these combined means, a ventilation as perfect as, and possessing more regularity than that resulting from open fire places, might be easily insured. These are all arrangements which would necessarily be left to the individual householder to arrange for himself. The heat supply may be utilized for purposes of ventilation, as well as for purposes of warming, with very little difficulty.

In discussing the degree of economy effected by the arrangement, the consideration of the collateral consequent saving of labor must be allowed due weight. In a moderate-sized house the annual consumption of coal will not be less than twenty tons; these are stowed in the cellar, and then carried thence in scuttles, which hold about 28 lbs. each—that is to say, at least 2000 separate coal scuttles full have to be taken to various parts of the house, the ashes brought down again, and much labor devoted to removing the dust, with which an open fire covers the furniture. In a moderate-sized house, the complete use of steam would enable, probably, one female servant to be dispensed with. In artisans' houses, the saving of trouble, by having no fires to attend to, no grates to clean, and no coals to carry, would be of much value. In addition to this, each fire deposits much soot in the chimney, which at regular intervals is pushed up into the air by the chimney-sweep, and thus distributed through the neighboring houses, rendering continued cleaning necessary, and

compelling a large annual outlay in repainting and re-decorating. There is also a great inconvenience to street traffic, caused by distributing coals to every house in every street.

The published reports do not furnish any satisfactory data by which the economy of the system can be tested relatively to other methods of heating. The following facts, however, are taken from the published reports. When the Holley Steam Combination Heating Company commenced operations at Lockport, in 1877, in the absence of all previous experience as to the cost of manufaaturing and distributing steam, the company supplied heat at a price equal to the previous average cost of coal to each consumer, with satisfactory results to all concerned. As an example, the school house measured 105,000 cubic feet of air space to be heated. The average annual cost of fuel, labor, repairs, &c., had been about £130; of these £60 was for the item of coal. The company therefore agreed to maintain a temperature of seventy degrees from 8 o'clock a. m. to six o'clock p. m. for £60, and the warming and the ventilation of the building gave entire satisfaction to the trustees and the pupils. It is stated that experience, thus far, rather tends to diminish than increase the expense of steam heating, and that the company have reduced their charges for heating that school house to £54 per annum.

It was regarded as no small item, by the first year's consumers, to be saved the annoyance of handling coal, ashes, kindling, &c., also the expense of stoves and repairs; but further experiment has led some steam companies to lump their charges for steam at 8s. per thousand cubic feet of air space per annum, which was found to be a still greater economy; but upon the introduction of the meter, made to register about the rate, a further saving might be effected by cutting off radiators in upper rooms, parlors, &c., when not in use, and paying only for the steam actually consumed. Thus, a house of 60,000 cubic feet contents, which is about the capacity of a good class London house, would pay about £24 a year for heat; whilst an artisan, in a model dwelling, which occupies, probably, from 6,000 to 8,000 cubic feet, would pay from £2 4s. to £3 4s. for heat a year, equivalent to from 10d. to 1s. 3d. a week. This is in the United States, where the winters are intensely cold, and where a very considerable amount of heat is necessary during the whole winter. On the other hand, if the steam were paid for by meter instead of by the cubic space, individuals using it might effect a reduction of cost, by cutting off the steam from the radiators in unoccupied rooms.

In Detroit, the company for heating by steam also supplied engines with steam for power. The experience of Detroit, as already mentioned, demonstrates the fact that 60 lbs. pressure could be maintained in four miles of 10-in. and 6-in. pipes, against the drafts for power and heat along the line. The last accounts which the author has seen from Mr. Gordon Lloyd, the engineer of the Detroit Company, states that the company heated a variety of buildings, stores, offices, two banks, one publishing office, one boot and shoe manufactory, &c, belonging to nineteen distinct owners, with an aggregate cubic capacity of 3,300,000 feet, in addition to which it furnished power to eight different establishments, varying from 2 to 65 horse power; in the aggregate, 196 horse power.

The cost last year was about the same as that of private heating, but it would be less on a more extended scale, provided the consumers be not too scattered, necessitating an undue proportion of street main. It is not practicable in cities to return the water of condensation to the boilers, which generally is a great economy, and would be done in all private or isolated cases. Mr. Lloyd, however, considers that the combination of heating with the supply of steam power is not advisable, because, whilst the pressure required for the latter is at least 50 lbs., for heating purposes from 3 lbs. to 5 lbs. would suffice.

If, however, the company which supplied the steam for heating was so located as to be able to supply some factories close to its boilers, and then to apply the steam which had been used for their engines for domestic purposes, considerable advantage and economy might result. And it would be an enormous convenience to a very large number of trades, to shops, to hotels, and to many other places, for a supply of steam

to be at hand for working lathes and other small machines, for lifts, and other labor-saving appliances.

The broad principle which the Holley Steam Combination Company has enunciated is that of furnishing heat from a central source of supply, applicable to all domestic purposes, just as gas and water are now supplied; and a list of thirty towns in the United States has been published, in which it is stated that this system is now being applied. It has therefore attained a practical development.

There are, doubtless, many advantages in the open fire-place, amongst which we may class its radiant heat, which warms us whilst it allows us to breathe comparatively cool air; its ventilating power; and the comfort which enables each occupant of a room, by selecting his position, to regulate according to his wishes the amount of heat he derives from it; and no one can feel more strongly than I do how great a loss its abolition would be.

But, on the other hand, with ingenuity and care, it would be quite possible to devise arrangements, in connection with steam heating, which would possess many of the advantages of an open fire; of course, the cheerful blaze could not be replaced; but when it is considered how much our open fire-places do towards polluting the air of a large town with smoke and soot, and all their concomitant evils; when we consider that London which now numbers nearly 4,000,000 of inhabitants, will, at its present rate of increase (a rate which has not varied since the beginning of the century) number nearly 8,000,000 in 1920; when we consider what a vast amount of labor to the community is entailed by the use of an open fire in every room, in the carriage of fuel, the cleaning of grates, and the dirt arising from the air polluted with soot; when we consider that these evils are being daily intensified by the rapid increase of London, and that most of these would be avoided if our supplies of heat were laid on from a central source, we cannot but feel that our advancing civilization, and our large congregations of dwellings, require, therefore, the adoption of some system for the supply of heat, which will enable us to dispense with separate supplies of coal to each house. The Combination Steam-heating system possesses many advantages, and in the rapid extension of houses which is continually taking place round our large towns, it is to be hoped that a trial may be given to the system in this country.

OUR NATIONAL AREA.

By FRANK D. Y. CARPENTER, C.E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

INASMUCH as the geographical extent of a country is in some sense the measure of its importance among nations, it is often desirable to know this area with some approach to accuracy. Searching through gazetteer, geography, encyclopedia, and statistical almanac, the student of political affairs will find the superficial contents of the United States, exclusive of Alaska, variously stated in figures, ranging from 3,000,000 to 3,050,000 square miles. For instance: *Lippincott's Gazetteer* gives 3,002,852, and the *American Cyclopedia*, 3,026,494 square miles. These values are not given in round numbers, as the results of a rough approximation naturally would be, but show an attention to detail which would not do discredit to the estimates for a Nicaragua canal, or to a modern jury's award of damages, and which indicates that precision has been aimed at if not attained.

Such wide discrepancies perplex and astonish the reader accustomed to believe in the infallibillty of mathematical processes, and it may not be uninteresting to discuss certain causes which may give rise to these differences. They may result from erroneous methods of computation and measurement of areas; from an ignorance of the geographical position of our territorial outline, owing to a want of accurate surveys; or, what is more

likely, from a variance of opinion as to the meaning of the expression, "our territorial outline."

By means of formulas now in use in our Census Bureau it is possible to compute the approximate area of a zone of the earth's surface included between two parallels. If this zone is restricted in width to one degree of latitude, the resulting area is practically correct. It is also found most convenient to limit the length of this belt to one degree of longitude, and thus the unit of surface becomes a square degree. If the country to be measured is a quadrilateral of our spheroidal surface, bounded by two parallels and two meridians, as Colorado and Wyoming, the determination of its area is reduced to the simple process of a summation of the areas of the square degrees contained within its borders. But there are very few political divisions on the face of the earth that are not limited, on one side at least, by an irregular, natural boundary, such as a seacoast, river or mountain range, or perhaps by some arbitrary line of demarkation, as the circular north boundary of Delaware, the geodesic line between Southern California and Nevada, or the traverse separating Connecticut from New York.

In this case it becomes necessary to consult the best maps obtainable, to find how large a portion of each square degree crossed by the boundary is included within it. This proportion of the fractional part to the whole degree, whose area is already known by computation, is easily found by the use of the planimeter; but as this mechanical contrivance is not reliable under certain unfavorable conditions, it should be used with caution and distrust. A safer way is the old-fashioned method of making, from the scale of the map, a reticle of squares on tracing paper, each square a square mile, and counting the spaces embraced in the territory in question. Even then it is generally necessary to apply a correction to the result, as a map is rarely found, even among the best, whose dimensions are not appreciably in error. Owing to faults in construction, the uneven shrinkage and expansion of paper, and to the distortion inevitable in all plane representations of the earth's surface, the length of a degree upon the map measured along the scale is seldom equal to the same degree upon the earth itself, and hence the square degree will be correspondingly too large or too small.

The second source of error is found in the incorrectness of boundary surveys. New and better surveys—later surveys generally are better—by enlarging or diminishing the territory inclosed, tend to invalidate all previous determinations of area. But there is little reason to anticipate any serious change from this cause in the future amount of our national domain. Our perimeter has been so accurately traced by the Coast and Geodetic Survey, the Mexican Boundary Commission, the Lake Survey, and the surveys of the British boundary, both in the north-east and along the 49th parallel, that there is not much room for subsequent fluctuation. The only uncertain gap remaining is the water chain extending from Lake Superior to the Lake of the Woods, and separating Minnesota from the British Possessions. The best maps of this region are probably those which accompany the reports of Professor Hind's explorations in that direction. A more systematic survey, some time in the future, will probably displace this boundary, as now understood, and thus add to or deduct from our national area.

While our country's ambit is so well defined along the British and Mexican borders that any considerable misconception of its position is not excusable, it is quite different along the coast front. The limits of our territory in that direction admit of no precise definition. Some patriots, anxious for the aggrandizement of their native land, would swell its area by counting in that strip of marine territory which skirts the shore and is subject to local jurisdiction, but this, for various reasons, is an extravagant and impracticable claim. In the first place, no one knows how far out to sea a nation's waters extend. There is nothing in foreign treaty or home legislation to establish, beyond dispute, this imaginary boundary of the high seas. Although there is a general impression that, by some kind of tacit international agreement, this limit is placed at three geographical miles from the land, this understanding, if such it can be called, does not even reach the dignity of unwritten law. A truer statement would be that

each power, while endeavoring to confine its fellow-nations within a three-mile belt of domestic waters, is inclined to assert its own sovereignty over much greater maritime area, extending its authority as far as permitted by the acquiescence and respect of its neighbors, and very frequently beyond this limit.

In the early part of the present century Russia proclaimed its ownership of all of the North Pacific Ocean above the 51st parallel; although this great gulf was four thousand miles wide at its mouth, the Russian autocrat contended that it was *mare clausum*, because surrounded by his territory on all other sides. In the days of her prosperity, Venice was the Queen of the Adriatic in reality as well as in name. From time immemorial England has held almost undisputed proprietary right to the King's chambers, those concavities of her shore which are hardly worthy of the name of bays, so distant are the headlands inclosing them. To come nearer home, the eminent jurist, Kent, speaking for the United States, reasons that our territory should be considered to embrace all of that portion of the Gulf of Mexico included by a chord reaching from the south point of Florida to the Mississippi River.

It may seem in keeping with the grandiose character of the Spanish people that it should extend its environ of national waters to a width of two marine leagues or six geographical miles. This was exemplified in our recent political imbroglio with Spain, arising from her molestation of one of our vessels off the Cuban coast, and which, as was maintained, was within six miles of the shore. There is, however, a basis of reason in this apparently ostentatious claim. The outer border of a nation's water is a presidial, or garrison line. It has been usually placed at three miles from the shore because that distance was in former times the extreme range of a cannon shot, and a nation's area was supposed to extend seaward as far as could be reached by the strong protecting arm of military power, lodged in a battery or fortress on the land. Now that a cannon ball can be thrown six miles there is no reason why the presidial line should not be located two leagues at sea, as in the case of Spain, with anticipations of a further extension to three leagues with future improvements in artillery.

Thus it appears that the marine possessions of a nation are co-extensive with the arrogance of its pretensions and the range of its cannon, and if it is so barbaric or insignificant as to be deficient in artillery it can make up in arrogance what it lacks in ordnance. Indeed, it has often happened that the most impotent and obscure peoples have been most presumptuous in their pretended sovereignty of the seas. In like manner Selkirk on Juan Fernandez, or Sancho Panza in Barataria, could have issued a proclamation placing his island realm among the first powers of the earth, as regards geographical extent. But such factitious territory, created by edict of king or congress, is as valueless as the fiat money which has no reserve of wealth behind it, and the United States is sufficiently vast in itself to disdain an inflation of its area with any of the waters of the open sea.

Going to the other extreme, there are some purists who would exclude all water, fresh or salt, from our national area. They forget that it is the intermingled water that makes the land valuable and habitable. The streams, lakes, and land-locked bays are as certainly as important a portion of a nation's wealth as an equal amount of solid ground, and are therefore as deserving of representation in that statement of area which we have assumed to be the measure of a nation's importance. If we except the wrecking and life-saving interests, and the proprietors of summer hotels and bath houses, it is difficult to name any direct benefit which accrues to New Jersey from its long stretch of open coast; but a sheltered arm of the sea, such as Raritan Bay, contributes to the welfare of the State in many ways. It is a gateway and outlet for the agricultural and mineral productions of the interior; it is a port of commercial entry and a harbor of refuge in case of storm; it is a quiet and safe fishing ground; and the land itself is not more jealously preserved and guarded than the oyster beds which cover the bottom of the bay, and which are a source of greater revenue than the average agricultural district yields.

The value to our country of New York Harbor is but faintly indicated by the

wealth of the cities which surround it, and which are immediately dependent upon it. The Bay of San Francisco has been of far greater service to the State of California than an equal extent of her richest gold fields. The sounds of North Carolina and the lagoons of Florida are useful as inland routes of commerce, and nothing would be gained by substituting in their place the swamps and pine barrens which abound on these coasts. The Mississippi River is but a narrow ribbon of water and yet it would take a very broad belt of cotton land and cornfield to compensate for its absence. Why should we enumerate the thousands of square miles of desert in Utah and leave out the area of Great Salt Lake, by whose beneficent influence a large portion of land otherwise arid is watered and made tillable. Nor is there any good reason for omitting an interior body of water like Lake Michigan from our national area, except, perhaps, that it is convenient to consider the United States as an aggregate of the individual States of which it is composed, and it is difficult to satisfactorily assign Lake Michigan and its tributary, Green Bay, between the two States by which they are enveloped. They can, however, appear under their own names in the list of the component parts of our nation's area, and be accompanied there by Delaware Bay and other extensive boundary sheets of water, whose possession may be disputed by the States which they separate.

If the foregoing opinions are correct the perimeter of a nation's area will coincide with its coast line, but this, unfortunately, is an expression scarcely less indefinite than the presidial line three miles beyond. Until the coast shall be traced by legislation, as it should be, so as to give a well-defined limit to our national waters, the geographer is obliged to rely upon his own judgment in drawing this outline, and, wherever he may locate it, his statement of an area is incomplete if the extent of surface included is not explained in the context or graphically illustrated on an accompanying map. Such explanation and illustration were prepared by the writer to accompany the areas of the States and territories determined by him for the Tenth Census, and will be found in the special bulletin on that subject, issued by the Geographer of the Census, Mr. Henry Gannett. It will be observed that the perimeter of the United States, as indicated by the red line on the map published therewith, includes Lake Michigan, whose area, however, is not given in the column of component parts of the United States, which sums up to 3,025,600 square miles. If to this sum we add the surface of Lake Michigan and Green Bay, which is 22,400 square miles, we have a grand total for the United States of 3,048,000 square miles, which may be adopted as a just and convenient expression for our national area.

In 1794 our Congress intimated a jurisdiction over a certain border of the sea by enacting "that the district courts shall take cognizance of complaints, by whomsoever instituted, in cases of capture made within the waters of the United States, or within a marine league of the coasts or shores thereof," but in neglecting to define "the coasts or shores thereof," it left our maritime boundary as unsettled as before; it is as if a surveyor should locate a station by referring it to some initial point or datum plane whose position was unknown. In a convention between France and England, held in 1839, it was agreed that the coast line, instead of invariably following low water mark, should cross the mouths of all bays and channels not more than ten miles in width. An arbitrary definition like this is not generally applicable, for it is evident that Chesapeake Bay, fifteen miles wide at the mouth and more than one hundred and fifty in length, can more properly be considered a portion of the United States, than some nameless concavity in the shore with a chord of ten miles and a depth of indentation of but two or three.

Many and interesting, and sometimes amusing, are the opinions of the lawyers upon this subject. Referring to the ocean boundary of a country, Lord Hale would have it cross such inlets of the sea as are so narrow that "a man may reasonably discern from shore to shore:" Hawkins agrees with him that this chord should not exceed the range of vision; and Story, more precise, would require this vision to be distinct and with the naked eye. The waters of the United States, mentioned in the Act of Congress

lately quoted, would include, according to Wheaton, "the ports, harbors, bays, mouths of rivers, and adjacent parts of the sea enclosed by headlands." Still more liberal, and therefore more unsatisfactory is the statement of Willcock, in his "Ocean, River, and Shore," that "it may be regarded as generally accepted that bays or channels within the horns of promontories and headlands, however large, are subject to the sovereign of the neighboring land." Under the generous terms of this definition our Atlantic coast would extend in a straight line from Maine to Florida. The makers and expounders of our laws do not seem to realize that there are no straight lines in an ocean shore, but that it is a succession of curves, terminated by capes, and that a chord, from promontory to prom ontory, may be taken at will from one mile to a thousand miles in length.

While a nation may lose territory from natural causes, such as the subsidence of its shores and the erosion of the banks of a boundary river, there is, on the whole, a greater tendency towards a gain of area, for this increase may result not alone from the upheaval of its coasts and the shifting, in its favor, of a boundary channel, but also, and principally, from alluvial deposits about the mouths of its rivers. By this gradual process the delta of the Mississippi River has been won from the Gulf of Mexico. This invasion of Neptune's dominion is still in progress, as is evidenced by the amphibious condition of the Louisiana coasts, here land and there water, sometimes flooded and sometimes dry. It may puzzle the computer to determine whether to include this disputed belt in the area of the United States, but, looking to the future, when all of this will be habitable ground, it is no more than just to give ourselves the benefit of the doubt, and count it in. This has already been done in the courts of law by Lord Stowell, who once decided that the Louisiana shore, to be accepted as the inner border of our neutral waters, should follow the extreme edge of the islands of debris and the alluvial flats now in process of growth.

Embarrassed by this variety of opinions from the best authorities, it is not strange that the computers of our national area should have disagreed in their results; but due attention being given to the foregoing difficulties, there is little excuse for the remarkably wide range of their wide disagreement. As has been said, the main source of discrepancy will henceforth be found in the adopted position of our national line of *enceinte*, but even here there are certain general principles of guidance in which, it is thought, all will acquiesce. These are that our outline should include half of all boundary rivers and straits; those arms of the sea which are decidedly land-locked, the depth of recess bearing an important ratio to the width of mouth, and especially those bays and harbors which are of advantage to the industries and commerce, and should exclude the great lakes of our northern border, which, in their general conditions, resemble the sea itself. All of these things being considered, however, a perfect coincidence of results, should never be expected, and if two independent determinations of the area of our country, made by geographers of equal judgment and facilities, should differ less than a thousand square miles, their agreement may be accepted as in a great measure fortuitous.

From the total area of the country we derive, by a process of deduction, the contents of the individual States. As the national outline has been much more accurately surveyed than the inter-state boundaries, in the same ratio the area of a single State is liable to have more than its quota of the error affecting the national area. But, by working always by square degrees and fractions thereof, the areas of the States will, in the end, amount to the national area, and the algebraical sum of their errors will thus be restricted in amount to the error of the country at large. Indeed, so little known are some of the boundary lines between our political divisions, that it is quite possible that the error in the area of a single State or territory may exceed the error of the country as a whole. Take, for instance the adjoining territories of Idaho and Montana. They are separated by the Bitter Root Mountains, of whose geographical position almost nothing is known. Some day a good survey will probably displace them by many miles from their present place on our best maps, and will thus correct the areas of

these territories by thousands of square miles. But what will be Montana's loss will be Idaho's gain, or *vice versa*, and the national area will remain unchanged.

Until the recent careful determination by the Census Bureau, the published areas of our States and territories have been but little better than traditions, descended from nobody knows where and when. Not more than half of them have approached within a thousand square miles of the truth; but while some have been too large, others have been too small, and thus there has been a partial compensation of error, and the national result has not been so seriously wrong as might have been expected. In all except the latest publications, the area of California is erroneous by thirty thousand square miles. As for Alaska, with its extensive boundaries of unsurveyed coast and unexplored mountain range, it will be very long before an idea can be formed, even moderately approximate, of its geographical extent. With a precision worthy of a better cause, Mr. W. H. Dall makes it 580,107 square miles. Its eastern boundary follows the summit of certain mountains, except where this range is more than ten marine leagues from the coast, in which case it is an artificial line ten miles from the sea. Nothing definite, however, is yet known of the position of these mountains, and we have but little knowledge of the thousands of miles of coast line, a large portion of it in Arctic regions, by which Alaska is inclosed. There is, therefore, room for a probable error of many thousands of square miles in its area, and it would have seemed justifiable in Mr. Dall to drop the odd seven miles from this result, and present his report in round numbers.

It is a fact possessing some interest that a determination of area, made by geodetic computations or by measurements from maps, as herein described, is slightly incorrect, inasmuch as the country to be treated is considered to be at the level of the sea, instead of at its real altitude. A portion of the earth's surface, inclosed by certain meridians and parallels, increases in geographical extent with its distance from the center of the earth, or with its elevation above sea level; it is, in fact, the base of a pyramid whose apex is at the earth's center, and it is evident that the solid angle at the apex remaining the same, the area of the base will increase with its distance therefrom. But all superficial dimensions of the earth are taken at the level of the sea, and are less than they would be if directly measured upon some upland plain, and hence all maps which are constructed by means of these dimensions are correspondingly too small.

This gain, in area, resulting from elevation, is actual and not merely theoretical, and in countries of great altitude it is quite considerable, but it cannot be exactly determined because the mean height of the surface, upon which it depends, can only be roughly estimated. Where the area of a country is found by actual linear measurement along the ground itself, as, for instance, by our land surveys, the result is theoretically correct, but there is such an accumulation of error in the practial workings of a land survey, mile by mile, and acre by acre, that the method of computation is after all more reliable.

The little republic of Switwerland is highly favored in elevation and in consequent gain of area. In our country Colorado, one of the numerous Switzerlands of America, takes rank as the loftiest of our States and territories. According to Mr. Gannett, its mean altitude above the sea is 7,000 feet; while Mr. Louis Nell, author of a recent map of that State, would make it 7,100 feet. As both of these engineers have been engaged for years upon the geographical surveys of Colorado, it is safe to accept a mean of their results, 7,050 feet, or 2,350 yards. The resulting increase of area is seventy square miles, or 44,800 acres.

The United States as a whole, being composed of lower land, does not gain in equal proportion, but adopting Mr Gannett's estimate for its mean altitude, 2,600 feet, it would have about eight hundred square miles more than a corresponding fraction of the earth's surface at sea-level, and consequently more than its area as computed and published.

If the area of a country be defined as the amount of its exposed surface, it will then be increased by the irregularities of mountain and valley which give geological character to the landscape. A mountain has greater surface than a plain, just as the sloping roof of a house has

greater area than its floor. It is still a mooted question in some of our agricultural districts whether the man with a hilly farm has more land than his neighbor with a level one. Though he may not have greater acreage, as acres are bought and sold, that is, on a plane basis, yet he really has more surface, and therefore more soil, and, other things being equal, greater productive capacity. The farmer among the hills may find some consolation for the inconveniences of his lot in realizing that, the more numerous the slopes and the greater their angles, the more land does he get for his money.

How much the United States gains from this source could only be considered by speculation at long range, but it may afford a moment's pastime to make a rough estimate for the State of Colorado, which, with its interminable succession of precipitous mountains piercing the sky, and its valley after valley lying deep in the shadows, is especially blessed with this gift of unconsidered area. What even acclivity, then, extending over the entire State, as the roof of a house over its floor, would give an additional area equivalent to that furnished by its numerous mountain-sides, sloping at every angle of the quadrant? Although recognizing the tendency to exaggerate the value of the angle desired, few persons familiar with the serrated profile of Colorado scenery would suggest an incline of less than ten degrees from the horizontal. This would give an additional area of sixteen hundred square miles. An angle of five degrees would result in a gain of four hundred square miles. Taking a mean of these figures it seems safe to say that Colorado is indebted to her mountains for at least one thousand square miles of gratuitous area which has never yet been included in any statement of her geographical extent. Nor is this gain entirely profitless, as some may claim. These are not waste lands by any means. It is the mountain-top—the mother of rain, as the Indians call it—that gathers the snow and stores it for the gradual supply of the streams by which the plains are irrigated; and it is along the mountain-slopes, torn from the bosom of the earth by ancient upheaval and washed by the storms of ages, that her mineral wealth lies exposed.

THE INFLUENCE OF MATHEMATICS ON THE PROGRESS OF PHYSICS.*

From "Nature."

In discussing the value of a given study, a lecturer is by common consent allowed—sometimes even in private duty bound—to exaggerate the importance of his subject, and to present it to his audience enlarged, as it were, through the magnifying power of a projecting lens, so that the details with which he has necessarily to deal may be brought into more prominent view. In an introductory lecture, such as it is my duty to give to-day, the speaker need the less feel any scruples in following the usual custom, as different subjects are treated of in successive years, and the hearer may, after the lapse of a short cycle, strike a pretty fair balance between the various branches which have successively been brought before him. But although I might have felt tempted to-day to insist on the advantages of Applied Mathematics as a separate subject not only worthy of study, but second to none in interest and importance, and though I feel no doubt you would have accorded to me the indulgence which every body requires who endeavors to lay an abnormal stress on the merits of a single branch of human knowledge, I prefer to found the claims of the subject, which I have the honor to represent in this college, not so much on its intrinsic value as on the influence it has had on the progress of other sciences. For no subject can stand by itself, and the utility of each must be measured by

*A lecture, introductory to the Session 1881-82 of Owens College, Manchester, by Arthur Schuster, Ph.D., F.R.S., Professor of Applied Mathematics.

the part it takes in the play of the acting and reacting forces which weave together all sciences into a common web.

The growing importance of mathematics as an aid to the study of all sciences is daily becoming more apparent, and it may indeed be questioned whether at the present time we can speak of physics as apart from applied mathematics. Riemann's opinion that a *science* of physics only exists since the invention of differential equations is intelligible; but however close the connection between physics and mathematics may be or may become, their growth in the earlier stages has been altogether independent. Gallileo may be said to have been the founder of mathematical physics, and amongst his successors have been many who showed a greater inclination towards pure mathematics than towards physics proper. On the other hand, we can trace back the ancestry of our experimental physics and that of our modern popular books on science to the Middle Ages, where we reach J. Baptista Porta and his books on natural magic. Even eighty years ago the fullest account of the state of experimental science was to be found in *Wiegler's Naturliche Magie*, a book of twenty volumes, in which scientific experiments and conjurers' tricks are alternately described. But since the beginning of this century the importance of the mathematical treatment of purely physical subjects has steadily grown, and fifty years ago, the two sciences were already sufficiently united to induce the founders of the British Association to join them together into one section. From that time until the present year, when the mass of work necessitated a temporary separation, the experimentalist and the pure mathematician could be seen at the annual meetings listening, or at least appearing to listen, to each other's investigations, and the influence which men of science on these occasions had on each other may be taken to represent roughly the mutual influence of the two sciences themselves; it was substantial, though in great part unconscious. I could not attempt to-day to give you a complete historical survey of the effect which the contact—one might often say the collision—of the two sciences had on the progress of each; even that part of the subject which I have chosen for special consideration is too vast to be successfully confined within the limits of a single lecture, and an incomplete sketch is all I can offer.

The influence of mathematical investigations on physical theories is not restricted to any single stage, but makes itself apparent throughout the whole course of their evolution. Before a theory is even started, the mathematician is often necessary to prepare its way. He has to classify complicated facts in a systematic manner, and working backwards from the phenomena presented by nature, he endeavors to find out which of them are necessary consequences of others, and which of them require independent hypotheses for their explanation. It is in this way that the works of Poisson, Green, Gauss, and of all those who have followed in their footsteps, may be said to have laid the foundation of the theory of magnetism and electricity, although we do not yet possess any physical notions as to the causes of these phenomena. The true power of mathematics, however, comes into play only when the physical inventor has done his work, and has formed distinct materialistic conceptions, which allow themselves to be expressed by mathematical symbols. It is then that the consequences of the theory are to be worked out and tested by experiment. In order to be convinced of the truth of any hypothesis, the scientific world wants quantitative experiments. Numbers form the connecting link between theory and verification, and they always imply mathematical formulæ, however simple these may be. Often two rival theories are on their trial, and the mathematician is supposed to find out where their conclusions differ and where crucial experiments are most likely to decide definitely between them. It is remarkable, however, how much more often physical or even metaphysical considerations have decided between two theories than arguments derived from mathematical reasoning. So-called crucial experiments, as a rule, come either too early or too late. Sir Humphrey Davy's experiment was absolutely conclusive against the corpuscular theory of heat, but scientific ideas were not ripe yet for the discovery, and his experiment had no marked effect on the progress of science. The crucial experiment here

did not involve any mathematical deductions; it is otherwise with that which might have decided between the two theories of light. According to the corpuscular theory, light travels more quickly in water than in air; according to the undulatory theory, the passage through water is the slower, and this distinction is founded on the necessity to account mathematically for the laws of refraction. But when Foucault actually made the experiment, and gave a death blow to the corpuscular theory, that theory was already dead. There was then only one scientific man of note left who still viewed the undulatory theory with suspicion, and his suspicions were not allayed by the crucial experiment. But if mathematical deductions have not decided as often as they might have done between two rival theories, they have constantly strengthened and confirmed our belief in physical hypotheses by inventing new cases which might test the theory, and which might, if experiment supported the mathematical deduction, establish it on a yet firmer basis.

The most important of all the functions of mathematical physics, however, and perhaps the only one through which mathematics has had an unmitigated beneficial influence on the progress of physics is derived from its power to work out to their last consequences the assumptions and hypotheses of the experimentalist. All our theories are necessarily incomplete, for they must be general in order to avoid insurmountable difficulties. It is for the mathematician to find out how far experimental confirmation can be pushed, and where a new hypothesis is necessary. Facts apparently unconnected are found to have their origin in a common source, and often only a mathematician can trace their connection. It is here that the pure experimentalist most often fails. A new experiment gives results to him unexpected, and he is tempted to invent a new theory to account for a fact which may only be a remote consequence of a long-established truth. Many examples might be given to show how mathematics often finds a connection unsuspected by the pure experimentalist, but one may be sufficient. A ray of light passing through heavy glass placed in a magnetic field, in the direction of the lines of force, is doubly refracted as it comes out. To none but a mathematician is it clear that this is only a direct consequence of Faraday's discovery that the magnet turns the plane of polarization of the ray on its passage through the glass. Happily this fact was first worked out theoretically; had it been otherwise, we should have heard much of the power of the magnet to produce double refraction.

In addition to the many services actually rendered by mathematical treatment, the mere attempt to put physical theories into a form fit for such a treatment has often been invaluable in clearing the theory of all unnecessary appendages and presenting it in the simple purity which may bring its hidden failings to light, or may suggest valuable generalizations. Instead of dealing, however, in a general manner with the various ways in which mathematics have been useful in the prosecution of physical investigations, it will be better to give a short account of the growth of some of our physical theories, and to illustrate the subject of this discourse by a few digressions suggested by the historical development.

As a first example I chose the progress of the undulatory theory of light. There is no other branch of physics in which the power of mathematics has been more successfully shown, nor is there one which shows the relations of experimental to mathematical physics in a truer light. At first we had experimental facts ahead of theoretical explanations; then we had the undulatory theory, which placed theory in advance of experiment; and now again a reversal has taken place, and unexplained experiments will remain unexplained until we shall be able to form more definite ideas of the relations between matter and the luminiferous ether.

Huyghens first worked out scientifically the hypothesis that light consisted of the undulations of an all-pervading medium. But as those who adopted the rival theory professed to explain equally well all phenomena which were then generally known, the scientific world preferred to walk in Newton's footsteps, and to reject what they believed to be the complicated and unnecessary assumption of an universal medium. The corpuscular theory could easily explain

the ordinary laws of reflection and refraction. Its attempts to explain the colors of thin plates and the fringes of shadows were less successful, but experimental investigations of these phenomena were not sufficiently advanced to bring these facts prominently into view, nor had their true explanation as yet been given. It was only when mathematical analysis was applied to the undulatory theory that its enormous advantages were discovered. Neither of the men to whom we owe the greatest advance which has yet been made in the science of light was a professed mathematician. Young was a medical man, Fresnel was an engineer; nor was the subject, when these men took it up, in a state which would have attracted a mathematician. Conceptions distinctly physical had to be formed, and assumptions not quite satisfactory had to be made. The chief claim to our gratitude rests, not so much on the mathematical treatment they have given, as on the fact that they left the subject in a state sufficiently advanced to allow mathematicians, even without special physical proclivities, to take it up, extend it and establish its foundations more firmly than otherwise they could have done.

The different manners in which Young and Fresnel set to work to prove to the scientific world the truth of their favorite hypothesis, and the corresponding difference in their success is especially interesting for the purpose which we had in view. Both men had considerable mathematical ability, and of the two, Young perhaps had the greater inclination towards pure mathematics, yet he avoided wherever he could the use of mathematical symbols, and disdained to bring forward experimental verification for what he considered sufficiently clear without.* It is to Young that we owe most of the physical conceptions which have secured a final success for the undulatory theory of light. He was the first to explain the principle of interference both of sound and of light, and he was the first to bring forward the idea of transverse vibrations of the undulations of light. The most diverse phenomena were explained by him, but their easy explanation was a sufficient proof to him of the theory he was defending, and he did not trouble to verify his conclusions by extensive numerical calculations. It thus happened, that although Young was first in the field in furnishing the true explanation of complicated phenomena, Fresnel, applying mathematical analysis to a much greater extent, had a much more potent influence in turning the scale of public opinion in favor of their common theory.

Though Fresnel's first memoir was published fourteen years after Young had established the principle of interference, Young's writings had remained unnoticed by him as well as by the scientific world in general, and Fresnel was surprised and irritated to hear that another had been in the field before him. But every one must agree that the chief share in securing the final triumph of the wave theory belongs to Fresnel, nor can there be any doubt that this is due to the mathematical calculations which he applied to cases easily verified by experiment. For there is a great fascination in a table with one column headed "calculated," another headed "observed," and a third giving the differences with the decimal point as much to the left as possible. And it is right that such tables should play an important part in the history of science, for whatever the ultimate fate of a partially accepted theory, the one solid legacy which it will leave behind after its death is the array of numbers, for which in its successful stage it has given a sufficiently correct account.

Fresnel invented different pieces of apparatus to test Young's simple supposition, independently made by him, that waves may be made mutually to destroy one another by addition, the crest of one wave being superposed on the hollow of another. It is necessary that the waves should originally be derived from a single source of light, yet they must seem to diverge from two different points. The necessary experimental conditions were fulfilled by the ingenious device of reflecting the light from two mirrors slightly inclined to each other. The light diverging from the two images of one source was allowed to cross, and bands alternately luminous and dark were

* "For my part it is my pride and pleasure, so far as I am able, to supersede the necessity of experiments."—Peacock's *Life of Young*, p. 477. Abstract letter by Young.

measured at the places where the waves overlapped. A rough micrometer of his own construction served to measure the intervals between the bands at various distances from the mirror, and Fresnel succeeded in obtaining sufficient data to test his theory. It cannot be my purpose to follow Fresnel and to describe all the various devices which he invented to confirm his views, and to establish the true theory of diffraction. Though he succeeded in making a convert of Arago, the greatest authorities then living, and the most influential men in scientific matters, both Laplace and Poisson disdained to consider the theory. The mathematical basis on which the theory rested seemed to them to be weak and insufficient. No doubt they were right; for many assumptions made by Fresnel were daring, and only justified by the results of further more careful investigations; some of his assumptions even were inaccurate. It was only when the phenomena of polarization and double refraction were explained that Laplace acknowledged the great power of the undulatory theory, and with a remarkable inconsistency publicly stated his admiration for Fresnel's work, after a paper which is more unsatisfactory from a mathematical point of view than anything else written by Fresnel. The opposition to the undulatory theory offered by the strictly mathematical school no doubt prevented its rapid acceptance by the general body of scientific men, but it is doubtful whether its final success was delayed. On the contrary, Fresnel was spurred on to greater exertions, and the excitement caused by the violent views taken by the opposed parties rendered the question a burning one, which it was necessary to settle definitely. The impartial observers had, at the time of which we are speaking, one strong argument for suspending their judgment. One great class of phenomena, now known under the title of phenomena of polarization, were unexplained as yet, and it seemed doubtful to them whether the undulatory theory could successfully overcome the difficulty. Then, as before, it was Young who first gave the physical explanation, while it was reserved for Fresnel again to show how the explanation was sufficient to account numerically for all the observed facts.

Those who first started the idea of luminous undulations founded their belief in great part on the analogy between the phenomena of light and those of sound. In a wave of sound each particle moves in the direction in which the waves are propagated, and it was natural to make the same supposition for the waves of light. Yet the mass of unexplained facts forced Young to consider the alternative case of waves in which the motion is in a plane of right angles to the direction of propagation. The waves of water in which such a motion partly takes place may have given to Young the first idea of a supposition which, as he showed, could account for many apparently singular phenomena. But his want of taste for calculations, as well as for experimental verification, prevented him from reaping the full fruits of his fertile ideas. Fresnel tells us that when he first conceived independently the idea of transverse vibrations, he considered the supposition so contrary to received ideas on the nature of vibrations of elastic fluids, that he hesitated to adopt it, and he adds: "Mr. Young, more bold in his conjectures, and less confiding in the views of geometers, published it before me, though he perhaps thought it after me." But when once the question was raised Fresnel applied to it the patient skill which, either by strict mathematical deductions or by happy guesses and assumptions, surmounted all difficulties. The phenomena of double refraction and their connection with polarization were now explained, and all the varied phenomena of light seemed naturally to follow from the simple supposition of waves of transverse vibrations. Such a successful application of mathematical calculations to the investigation of physical phenomena had not been heard of since the time of Newton, and could not fail in the end to produce its due effect. The supporters of Young and Fresnel became more numerous and confident, and the scientific societies duly acknowledged the services rendered by both. Young was elected one of the eight foreign members of the French Academy, and Fresnel received the Rumford Medal of the Royal Society, which, however, only reached him on his death bed.

The undulatory theory now entered on a stage in which it could be taken up by

the mathematician pure and simple. Its foundations had to be rendered more secure, and its consequences had to be worked out to a greater extent than even Fresnel had done.

The scruples which hindered most of the French mathematicians from accepting Fresnel's views were shared by Poisson, who deduced from the equations a result apparently paradoxical. According to Fresnel's formulæ, the center of the shadow of a small circular disc formed by a luminous point should be as bright as if the disc were absent. But, however curious this result might be, it had been observed just 100 years before Fresnel's time, and as that experiment had been completely forgotten, Poisson's theoretical conclusion had again to be subjected to the test of experiment, when it was found to be completely in accordance with fact.

But the most remarkable discovery made solely by calculation was the so-called conical refraction, theoretically deduced from Fresnel's wave surface by Sir Wm. Hamilton. That great mathematician had found that a point, when looked at through a crystalline plate cut in a certain direction, should appear not as a point, but as a ring, and the fact was verified experimentally by Prof. Lloyd. This discovery has always been considered one of the greatest triumphs of mathematical physics, and justly ranks on equal terms with the discovery of the planet Neptune by Adams and Leverrier. It is necessary to remark, however, that strange and unexpected conclusions, especially when they have been arrived at after complicated mathematical transformations, tempt us sometimes to exaggerate the additional support which their verification gives to the theory by means of which those conclusions have been reached. It is extremely unlikely that any theory should account for all the facts explained by Fresnel, and not also for all those discovered by his successors. As a matter of fact, Fresnel's wave surface is not the only one which has been suggested, but as they all contain the singular points at which the conical refraction is produced, this phenomenon is no proof that Fresnel's equations are strictly correct. It often happens in mathematical explanations of physical phenomena that the equations orignally deduced contain a series of constants which are then determined to fit the experiments. This process, which is perfectly legitimate, does however often prove only that the theory is successful in giving us a useful formula of interpolation, and need not be conclusive in favor of the ideas which have led to the formula. In a considerable number of cases, such as the reflection of light from metals, and even the theory of double refraction, we have different formulæ which all give, as far as we can test them, a sufficiently correct account of the facts, and none of them therefore prove anything in favor of the views which the different authors of the equations have put forward.

Before leaving our consideration of the services rendered by mathematics to the undulatory theory, we must not forget to notice the mathematical investigations by means of which its foundations have been placed on a safe dynamical basis. The investigations of Cauchy, those of Green, which followed, but especially those of Stokes, have secured for this theory such a firm support that even Laplace might have accepted it without further scruples. As a matter of history these investigations have done little towards the final victory of the theory. They came too late to affect the course of events, but they have increased the confidence of mathematicians in physical theories, and have prepared the way for further investigations.

As I have already remarked, it is one of the great objects of mathematical physics to investigate how far we can safely push certain assumptions and where a new hypothesis must be brought into play. And, indeed, when we have carried our calculations as far as we can, when we have experimented and measured as much as we can, we find that the undulatory theory as it stands at present, though following up to a certain point with marvelous accuracy the true course of nature, shares the common fate of all theories, and leaves a vast quantity of facts unexplained and waiting for more complete investigations. Nor is this to be wondered at; our assumptions as regards materia media may in many cases give correct results, and no doubt answer very well as a first approximation, but we arrive at a point where such a ma-

terial medium can no longer be considered homogeneous, and here our conclusions must break down; but it is to mathematics that we must look for the next great step. The progress of the science of optics during this century has shown us how much mathematical calculation can help to establish a great and important fact, such as the existence of that all pervading medium, the vibrations of which constitute light, and I may review more quickly the recent progress of other branches of science.

In the science of heat we do not require mathematical calculations to show the superiority of the mechanical over the corpuscular theory. Sir Humphry Davy's experiment shows conclusively that heat cannot be a substance, and Joule's experiments served further to illustrate the great advantages of the mechanical theory. The mathematical treatment of thermic problems was not required to establish a theory, but was suggested by practical considerations. The important question, how much work we can get out of a steam engine first attracted mathematicians, and out of this question the present science of thermodynamics may be said to have arisen.* Carnot, who gave the initial impulse to these mathematical investigations, assumed in his papers that heat was indestructible, though he seemed personally inclined to prefer the mechanical theory, which denied that indestructibility. Carnot's investigations were only gradually appreciated, and it was only when Clausius and Thomson corrected his theory, so as to bring it into accordance with modern ideas, that general attention was directed to the subject. It was found that so many important consequences of physical interest (as the lowering of the freezing point of water by pressure) followed out of Carnot's corrected reasoning that the mechanical theory now rapidly made its way, and though, as already mentioned, the proof of its truth rests on a perfectly simple experiment, mathematics must be considered to have had an important share in the final establishment of that theory.

It seems impossible to speak of the services rendered by mathematics to the progress of our knowledge of heat without mentioning the great law of the dissipation of energy. No two sciences seem further apart than mathematics and metaphysics, yet mathematical propositions have often furnished material for metaphysical speculations on the workings of nature. Thus the many dynamical propositions involving minimum or maximum properties, such as the principle of least action, have been taken to show that nature always works with the least expenditure of force, and thus the important law of dissipation of energy, which asserts that the world must have a slow and gradual end, could not fail to be used in the discussion of its sudden and abrupt beginning. These metaphysical speculations react again on the progress of physics, but it seems doubtful how far this indirect influence of mathematics has been beneficial; at any rate mathematicians cannot be held responsible for such an extension of their power.

An offshoot of the mechanical theory of heat is the molecular theory of gases. The idea on which that theory is based is not new, but it remained a speculation merely until, chiefly through the labors of Joule, the mechanical theory of heat was experimentally established, and its laws investigated. There is, perhaps, no branch of science in which mathematics has had such unexpected results in forming and confirming our faith in purely physical conceptions. That matter is made up of atoms and molecules is an hypothesis which simplifies many physical and chemical problems. It may, on chemical grounds especially, be considered a highly probable hypothesis, but we could hardly have obtained the confirmation amounting to proof which the idea has received of late years, without the mathematical treatment which it has received at the hands of Clerk Maxwell and those who have followed in his footsteps. One of the most astonishing results obtained by Maxwell is the one subsequently verified by experiment, that so long as Boyle's law is true, the coefficient of viscosity, as well as that of the thermal conductivity in a gas, is independent of the pressure. This fact alone, which could never have been obtained without the aid of mathematics, is a sufficiently strong foundation on

* Foucauld's investigations, though of enormous mathematical importance cannot be said to have had a direct influence on the progress of physics.

which we may rest our belief in molecules. It would be extremely interesting to follow out the more recent developments of the mechanical theory of gases, and to show how both mathematics and the absence of mathematics have advanced its progress, but if it is a good rule to say nothing but good of the dead, it is a better one to say nothing at all of the living.

I have already alluded to the mathematical treatment of electricity and magnetism. The aid of mathematics here was not required to confirm a theory, but rather to prepare the way for one. The complicated laws, regulating the attractions of electric and magnetic bodies, and of bodies carrying electric currents, have by the aid of mathematics been reduced to their simplest form, and electrical units have been connected with the ordinary mechanical units. This interesting branch of physics will furnish us with an example of the services which mathematics has rendered in directing the efforts of experimenters into the proper groove. We need only compare the magnetic measurements which were made during the last century with those made in our own time. While the early investigations gave us only a series of numbers impossible to interpret without a large quantity of accessory data, which are generally omitted, modern measurements, even when made by non-mathematicians, have generally been suggested by mathematical calculations and very often serve a useful purpose.

I have hardly alluded, as yet, to the science of dynamics, which is the foundation of all applications of mathematics. Its progress has been steady since the time of Galileo, but all the marvelous results arrived at by Newton and his followers, results which first showed the great fertility of applied mathematics,are too familiar to need any enumeration from me. The modern researches in hydromatics may perhaps not as yet have led to any definite result of physical interest, but they are rapidly progressing towards that end, and we may look forward to an increasing number of physical discoveries made by the aid of mathematics.

In tracing the history of some of our modern theories, I have followed the usual plan of presenting the history of science as illustrated by the discoveries of our great scientific men. It is necessary however, to draw attention to the fact, and I have tried to keep this point in view throughout this discourse, that it is not always the most conclusive arguments which carry the day, and that second-hand thinkers often had a more potent influence in shaping the course of scientific history than those to whom we now justly ascribe the greater merit of discovery. In our historical studies, therefore, we ought to direct our attention not less to that which has influenced public opinion,than to the actual soundness and originality of each discoverer.

If we ransack old books of science we often come across passages of long-forgotten writings, in which, when they are properly construed, when new meanings are given to old words and obscure expressions are freely translated, we may trace a faint prophetic glimmering of a modern theory. Such passages have a peculiar charm for the student of scientific history; they are often the only reward for much patient and otherwise useless reading, and are interesting as showing the almost boundless ingenuity both of him who made the statement and of him who interpreted its meaning. But those who are fond of this process of exhumation ought not to forget that two parties are necessary to every advance in science—the one that makes it and the one that believes in it, and the course of history is as much affected by the second class as by the first.

> "A jest's prosperity lies in the ear
> Of him that hears it, never in the tongue
> Of him that makes it."

A scientific man, in so far as he influences the progress of science cannot be far ahead of his time, and though his writings may be read and admired centuries after his death, he will have written in vain if he has not been appreciated by his contemporaries or by those who immediately followed. For our present purpose, then, we must consider not so much those mathematical arguments which appear now to us the most conclusive ones, but such as did appear conclusive to those whose opinion they were meant to affect. But if we try to discover what arguments have had the greatest power in removing old preju-

dices and in causing a solid advance in science, we find that they have often been of the most flimsy nature. Analogies, sometimes not even good ones, have succeeded where solid reasoning has failed, prejudices have been overcome only by other prejudices, and a rough illustration of a point of secondary importance may have made a previously obscure theory look more familiar, though not more clear, to the popular mind. What, for instance, has the existence of Jupiter's four satellites to do with the question whether the earth turns round the sun or the sun round the earth? Yet the discovery of these satellites has produced a greater revolution in favor of the Copernican theory than anything else that Galileo wrote on the subject.

If we look at the history of science from the point of view suggested by these considerations, we find that in addition to the legitimate influence of mathematics which we have traced, its practical effects, through less reasonable causes, have often been as powerful. The statement that in science authority is of no avail against argument, is one the proof of which must be looked for in the future, rather than in the past. There can be little doubt that authority has had a great effect in all scientific revolutions, and the authority of mathematicians was always greater than that of other men of science. Men are thoroughly convinced in one of two ways only; either by a train of reasoning which they can fully appreciate, or by one which is entirely above their comprehension. To those who are particularly amenable to the second kind of proof, mathematics has always been a magic power. Many results first obtained by the help of advanced mathematics have since been deduced by more elementary reasoning, but it seems questionable whether the original author would have been as successful in overcoming the inertia of his contemporaries, if he had confined himself to language intelligible to the greater number of his readers. It is no doubt due to this cause that mathematical papers have brought with them more widespread convincing power than we should now feel inclined to accord to them. The papers of Young, in which he avoided symbols, may appear to us sufficient to establish the undulatory theory of light; the arguments of Sir Humphry Davy, the experiments of Joule, may seem absolutely conclusive in favor of the mechanical theory of heat; but although the mathematical investigations of Fresnel, Clausius, and Thomson could be appreciated only by a much smaller number of readers, they had a more powerful influence in turning the scale of public opinion in favor of the modern ideas. It seems sometimes almost as if it required an experimentalist to convince a mathematician, and a mathematician to convince the general world. It is impossible to enter into greater detail or to exemplify more amply the assertions which I have made without touching on delicate and controversial matters, but on the present occasion it seemed to me to be specially fitting to point out that the course of science is as much affected by the appreciative faculty of receptive minds as by the creative faculty of the discoverer.

It is given to a few only to take an active and successful part in the production of scientific work. The young man who begins life with the idea of making a name as a scientific discoverer is like the little girl in *Punch* who intended to become a professional beauty. They may both be successful, but if so, it will depend as much on the ready appreciation of their contemporories as on themselves. The advance of science takes place through many channels, and each generation has its own part to play. Particular ideas, particular faculties are wanted at particular times, and no one can foretell where success will be. Men who are now quoted as shining lights would have passed away unnoticed had they lived at other times, and many a life has been one of patient but unsuccessful work, because its energies were devoted to a subject which was barren, or at least lay fallow for a time. No one, for instance, who has attempted to read through J. B. Morinus' work (and I doubt whether any one has ever got beyond the attempt) can fail to notice in him qualities which might have made a successful discoverer. In his method of determining longitudes by lunar distances Morinus has left us a lasting legacy. During the greater part of his life, however, his energies were devoted to the study and application of astrology

and all the labor spent on that subject was thrown away, although he did his best to make his own prophecies come true, and, having predicted the end of the world for a certain year, went through with his share of the proceedings, and died a natural death at the appointed time. *A priori*, there was no reason why astrology when married to mathematics should not have produced a healthy progeny, and looking especially to the state of science at the time, we can have little fault to find with the old astrologers; it is only the long and sad experience of their failure and disappointment that has given us the right to laugh at their unproductive efforts.

History then does not teach us any royal road to success. But more important for the ultimate progress of truth than a solitary success is the training of the faculty which enables the scientific man to judge correctly, and to appreciate the results of those who strike out new roads and extend the boundaries of knowledge. It seems to me to be one of the chief objects of an institution like this to bring up men, who, by conscientious consideration of scientific speculations, may help to give that solidity and elasticity to public opinion which is necessary for the rapid advance of science.

If I say that the study of applied mathematics is pre-eminently fitted for the improvement of an acute and correct judgment, I only express a sentiment which, I am sure, is felt by each of my colleagues for his own subject. Where so many attempts are made, let us hope, that one may have the desired effect.

THE PRODUCTION AND USE OF GAS FOR THE PURPOSES OF HEATING AND MOTIVE POWER.

By J. EMERSON DOWSON.

From the "Journal of the Society of Arts."

It is hard to realize that so extensive a use of coal gas for illumination has been developed during little more than half a century. Fifty years ago, nearly all towns were lighted, or said to be lighted, with miserable oil lamps, and now the capital publicly invested in works for the supply of gas in the United Kingdom amounts to something like 45 millions; and, for London alone, it is over 13 millions sterling.

The manufacture of lighting gas, on so large a scale, has naturally led to the improvement and cheapening of its production; and this, again, has led to its more extended use for lighting, and to its adoption to a certain extent for heating and motive power. This more general use has led us to become familiar with the advantages of gas as a fuel; but we have also learnt the unpleasant fact that its use for such a purpose is generally attended with much more expense than when coal or coke fires are used. We now know that gas engines are theoretically more efficient than hot air or steam engines, and we know that they cannot burst like steam boilers; but their general adoption is greatly impeded by the high price of the fuel they require.

Ordinary coal gas is also admirably adapted for cooking and innumerable heating purposes, but in the hands of careless persons (and they outnumber the careful ones) it is certainly not economical, compared with coal or coke. Supposing, however, that gas were at such a price that it could be extensively used for fuel, its consumption would be enormous, and as it would greatly reduce the quantity of raw coal used in open grates, the smoke nuisance, from which we suffer so seriously in large towns, would, without doubt, be sensibly abated. We see, therefore, that much may be gained by our having suitable gas at a low cost for heating and motive power, but we have not yet determined how this is to be accomplished. It is, however, a question bearing directly on our health and comfort, and on fuel economy; and as such, it is one of national importance, and therefore deserving of our best attention.

What we really have to do is to con-

sider separately the question of gas for lighting, and of gas for heating; and until this is done, and until we appreciate the principles involved in each case, I fear we shall not arrive at sound and practical conclusions. First, therefore, it will be well for us to remember that, after all, our so-called lighting gas has a very small percentage of illuminating constitutents. Rich Manchester gas has only about 6½ per cent., and ordinary London gas so little as 4 per cent. Roughly speaking, average London gas consists of hydrogen, 52 per cent.; marsh gas, 35 per cent.; carbonic oxide, 8 to 9 per cent.; and olefiant gas, 4 per cent., so that in every 100 cubic feet we have about 96 cubic feet of non-luminous heat giving gases, and only 4 cubic feet of luminous gas. The addition, however, of this small proportion of illuminants adds very greatly to the trouble and cost of preparing the gas, and although this addition is essential for lighting, it is not in the least necessary or desirable for heating purposes.

In the phenomena attending the combustion of lighting gas, the non-luminous heating gases serve to raise the temperature of the carbon particles to a white heat, and it is the incandescent carbon which produces the lighting effect. It is, therefore, consistent with the teaching of science, that there should be a large preponderance of heat giving gas present with the lighting gas, although we have certainly not obtained the best possible proportions in our London gas. We have now to consider what occurs when we use lighting gas for heating purposes, and we shall see that other conditions then obtain. As a matter of fact, when such gas is used as a heating agent, the first thing we almost invariably do is to destroy its luminosity, by the Bunsen, or other atmospheric burners, or blow pipes, used. Here I have a jet of ordinary lighting gas, and if I wish to heat a vessel with it, I cannot let the gas touch the vessel without a deposition of soot, owing to its cooling effect on the flame, and this involves a loss of heat, the soiling of the vessel, and a waste of gas. If I place the gas jet so far under the vessel that the tip of the flame is not in contact with it, I lose much heat, radiated from the sides of the flame, and in cases where a concentrated heat is required, there would also be difficulty in burning the needful quantity of gas. To meet these difficulties, we use a burner, or a blow pipe, which causes a certain quantity of air to mix with the gas before it is ignited. But, as you see, the immediate effect of this is to destroy the luminosity of the flame, for the carbon is brought into such close proximity to the oxygen of the air, and their chemical combustion takes place so rapidly, that apparently there is no intermediate stage of incandescence.

It is true that olefiant gas has a high calorific power, but it is less than that of hydrogen or marsh gas, and it can be well replaced by either of the latter, where heat only is required. We see, therefore, that the presence of the costly illuminating constituents in ordinary coal gas is not only unnecessary for heating purposes, but adds considerably to the difficulty of using it. It then naturally occurs to one to ask, are we right in adhering to the ordinary method of producing gas when required for heating purposes, and cannot other suitable gas be obtained at less cost than ordinary lighting gas? It is my belief that both these questions can be answered in the affirmative, and I will give you my reasons.

In the first place, it has long been established, and is well known, that highly-heating non-luminous gases can be produced by decomposing steam in the presence of incandescent carbon, and it only remains to prove that the process can be carried out in a simple way at a moderate cost. Dr. Siemens was the first to prove to the world on a practical scale, in connection with regenerative furnaces, the great economical and other advantages of using cheap gaseous fuel. This is now matter of history, and his system, or some close imitation of it, has been adopted in all manufacturing countries. In the Siemens gas producer, air only, or air mixed with a small quantity of steam, passes through a mass of red-hot fuel, and gas so made, answers extremely well when used in large quantities, and when highly heated in the regenerative chambers of a furnace. It, however, contains 60 to 70 per cent. of nitrogen, and this large proportion of incombustible gas renders it unsuitable for use in small quantities, as for instance,

in ordinary gas burners, or in gas engines, &c. Many other systems have been tried, but it would serve no useful purpose, here to describe all that has been done in this direction. Suffice it to say, that the early attempts chiefly consisted of passing steam through iron retorts, charged with carbonaceous fuel, rendered incandescent by external fires. The steam was decomposed, and some of the oxygen combined with the carbon of the fuel, but some of the oxygen also combined with the iron of the retorts, and the process was necessarily abandoned. Messrs. Kirkham introduced the method of decomposing steam by passing it through a column of fuel previously rendered incandescent by an air blast. In this way external fires were dispensed with, and as the retorts could then be lined with refractory material, their oxidation was prevented, and the working cost was considerably reduced. Air was first forced into the generator, until the temperature of the fuel was very high. The air inlet was then closed, and steam was let in. The latter was at first readily decomposed, but at the expense of much heat withdrawn from the fuel; and soon it was necessary to turn off the steam and again introduce the air blast. To make up for the want of continuousness in the process, two generators were worked alternately, and this, and the constant variation in the temperature of the fire, caused serious fluctuations in the quality of the gas.

Many modifications of Messrs. Kirkham's apparatus has since been introduced, but nearly all depend on the intermittent passing of air and steam through the fire. We have already seen that Dr. Siemens has, in some cases, adopted the plan of passing a mixture of steam and air through a fire, and although his gas is weak, it has the advantage of being continuously produced, and of being uniform in quality. In 1875, Mr. J. Kidd patented an apparatus by which he made somewhat similar gas, and a paper on it was read before this Society, in April, 1878. The chief novelty in this apparatus was the placing of a coil round the sides of the gas generator, so that water introduced into the coil might be converted into steam by the heat of the generator fire, the steam thus produced being afterwards passed through the fire, and there decomposed. This answered well when the fire was carefully attended to, but if it was neglected for a short time, wet steam and water passed from the coil, and the ap-apparatus soon became unmanagable. Careful experiments with this gas showed that its calorific power was only 20 per cent. that of ordinary London gas, while the temperature of combustion was also much less than that of the latter.

With your permission, I will now describe briefly the apparatus of which there is a model before you. This model is half the actual size of a generator which produces 1,000 cubic feet an hour. In this system I have imitated Dr. Siemens and Mr. Kidd, in passing a mixture of steam and air through a fire, but I have adopted special means for producing and superheating the steam, and for maintaining all the conditions of working constant and simple, and by so doing, I have sensibly improved the quality of the gas produced. A full-size vertical section of the whole apparatus is shown on the diagram, and from this it will be seen that the steam producer and super heater consists of a long length of tubing bent in such a way as to bring nearly the whole of it over some gas flames underneath. Water, at a pressure of 20 to 25 lbs. per square inch from a town supply, from an overhead cistern, or from a pump with accumulator, is passed into the coil, and there converted into super-heated steam. When the cock regulating the inlet of water has been adjusted, and when the gas has been lighted under the coil, the conditions as to temperature and pressure are constant, and this part of the process needs no further attention. The gas required for heating the coil is drawn from the gas holder, but on the first occasion of starting the apparatus, or whenever there is no gas in the holder, a fire is lighted on a grate under the coil. The retort, or generator, has an iron casing, to make it gas-tight, and this is lined with ganister, as in a foundry cupola, to prevent loss of heat and oxidation of the metal. The fire rests on a grate, and under the latter is a closed chamber, into which a jet of the super-heated steam plays, acting as an injector, and carrying with it, by induction, a continuous current of air. The pressure of the steam forces the

mixture of steam and air upwards, through the fire, so that a high temperature of the fuel is maintained, while a continuous current of steam is simultaneously decomposed. In this way the working of the generator is very regular, and the gas is produced rapidly, and without fluctuations in quality. The well known reactions occur; the steam is decomposed, and the oxygen from the steam and air combines with the carbon of the fuel to form carbonic acid, which is reduced to the monoxide on ascending the fuel column. Approximately, the composition of this gas by volume is, hydrogen 20 per cent., carbonic oxide 30 per cent., carbonic acid 3 per cent., and nitrogen 47 per cent.

Where uniformity of pressure is required, as for engines, burners, &c., or where storage is needed, the gas is passed into a holder. This somewhat retards the production, but the injector causes gas to be made so rapidly that a holder is easily filled when weighted to give a pressure of 1″ to 2″ of water, and at this pressure a generator can pass gas continuously into the holder, while at the same time it is being drawn off for consumption. For boiler and furnace work, the gas can be used direct from the generator, and in such cases, where there is no gas holder, I do not use the super heater above described, but I produce the steam in the gas generator itself. Instead of solid bars for the grate, I use hollow ones, and these I connect together in such a way that the water or steam passes through each bar successively. The heating of these bars is not liable to fluctuations, because the heat to which they are exposed is but slightly affected by any variation in the fuel column above them.

The nature of the fuel required depends on the purpose for which the gas is used. If for heating boilers, furnaces, &c., coke or any kind of coal may be used; but for gas engines, or any application of the gas requiring great cleanliness and freedom from sulphur and ammonia, it is best to use anthracite, as this does not yield condensable vapors, and is very free from impurities. Gas made by this process, and with anthracite coal, has no tar and no ammonia, and the small percentage of carbonic acid present, does not sensibly affect the heating power. A further advantage is, that it cannot burn with a smoky flame, and this is of importance for the cylinder and valves of an engine, and renders it much more easy to apply it to cooking and other stoves than when lighting gas is used. At present, all gas stoves are but compromises, for some of the difficulties attending the use of ordinary lighting gas for cooking and heating purposes are so great, that the makers have failed to overcome them. With a gas, however, which requires little air for its combustion, and which cannot give off smoke or cause a soot deposit, these difficulties nearly all disappear.

About seven pints of water and 12 lbs. anthracite produce 1,000 cubic feet of my gas, but $\frac{1}{10}$th, $\frac{1}{12}$th, and $\frac{1}{15}$th of the gas so made is required to produce and superheat the steam in the A, B, and C sizes respectively of the apparatus used. We have, therefore, an effective production of 900 to about 930 cubic feet, or a mean of, say 915 cubic feet per 12 lbs. of anthracite, allowing 8 to 10 per cent. for impurities and waste. A ton of anthracite produces therefore 170,740 cubic feet, of which about half are combustible.

The cost of manufacture depends to a certain extent on the scale of working, and the figures I am about to give you are unfavorable to myself, because they do not represent working on a large scale, when the expenses would be spread over a large production. No skilled labor is necessary, and in practice, where a single generator is required, it is usual to employ a man who has other work to attend to near the generator, and to pay him a small addition to his ordinary wages. A reliable statement of the actual cost of producing the gas in single generators of the three sizes in use, is given in the following Tables, 1, 2, and 3.

TABLE 1.

Generator A size (producing 1,000 cubic feet per hour).

	s.	d.
Anthracite=12 lbs. × 9 working hours= 108 lbs.—or, say 1 cwt. at 15s. a ton..	0	9
Allowance for wages of attendant.....	1	0
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £125= per working day.....	0	5
Interest on capital outlay.....	0	5
Total.....	2	7

	Cubic feet.
Gas produced	9 000
Less gas used for generating and superheating steam	1,000
Total effective gas for 2s. 7d.	8,000
Net cost, say 4d. per 1,000 cubic feet.	

TABLE 2.

Generator B size (producing 1,500 cubic feet per hour).

	s.	d.
Anthracite=18 lbs. × 9 working hours= 162 lbs.—or, say 1½ cwt. at 15s. a ton	1	1½
Allowance for wages of attendant	1	0
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £140= per working day	0	5½
Interest on capital outlay	0	5½
Total	3	0½

	Cubic feet.
Gas produced	13,500
Less gas used for generating and superheating steam	1,200
Total effective gas for 3s. 0½d.	12,300
Net cost, say 3d. per 1,000 cubic feet.	

TABLE 3.

Generator C size (producing 2,500 cubic feet per hour).

	s.	d.
Anthracite=30 lbs. × 9 working hours= 270 lbs. at 15s. a ton	1	9½
Allowance for wages of attendant	1	6
Repairs and depreciation of generator, gas-holder, &c., 5 per cent. on £160= per working day	0	6½
Interest on capital outlay	0	6½
Total	4	4½

	Cubic feet.
Gas produced	22,500
Less gas used for generating and superheating steam	1,500
Total effective gas for 4s. 4½d.	21,000
Net cost, say 2½d. per 1,000 cubic feet.	

From these Tables it will be seen that, allowing 1s. to 1s. 6d. a day for the proportion of the attendant's time required for feeding the generator, the total cost of production (including depreciation, and interest on capital outlay) is 4d., 3d., 2½d., for the A, B, and C sizes respectively, or a mean of about 3d. per 1,000 cubic feet.

The calculated calorific intensity or the pyrometric effect of London gas of the composition before stated, is 2554° C. (4629° F.), and of my gas 2268° C. (4114° F.) The calculated calorific power of 100 liters of the London gas, or the number of grammes of water which they can raise one degree Centigrade, is 559,038, and of 100 liters of my gas 155,836 grammes. From these figures you will see that 3.5 volumes of my gas are required to give the same calorific power as one volume of the London gas, and therefore we must multiply the cost as given in the tables 1, 2, 3, by 3.5, to give that equivalent of 1,000 cubic feet of the coal gas. Another practical consideration is that coal gas requires 224 to 250 lbs. of coal per 1,000 cubic feet of gas, but my gas requires only 12 lbs. per 1,000 cubic feet; and multiplying this by 3.5, to give the equivalent of 1,000 cubic feet of coal gas, we have 42 lbs. instead 224 to 250 lbs. This is only 16.5 to 18 per cent. of the weight of the coal required for coal gas; and in reference to the cost of transport, this will effect an appreciable saving in many outlying districts.

Although my apparatus is not very large, I cannot, of course, work it in this hall; but I have here a bag of my gas, and I will show you some of it burning. This is an ordinary Bunsen lamp, and before opening the air inlets, I would ask you to notice that when a piece of porcelain or bright metal is held over or in the flame, no soiling or deposition of soot takes place. I will now open the air inlets, and you will see that I can readily heat a piece of platinum, and that notwithstanding the presence of so much nitrogen in the gas, there is very considerable heat energy developed; in fact, the effect produced is very similar to that obtained with coal gas. This can be explained by the fact that one volume of ordinary London gas requires, theoretically, 5.24 volumes of air for its combustion, and yields 61.3 volumes of combustion products at the temperature of ignition, whereas one volume of my gas requires 1.2 volumes of air, and yields, at the temperature of ignition, 18.1 volumes of combustion products. If we then multiply the 18.1 by 3.5, we have a total of 63.3, compared with 61.3. as the volumes in each case, over which the heat of combustion is distributed. I have not gas enough here to make the experiment, but I may mention that I have fused ½ lb. of cast-iron in an ordinary Fletcher furnace of small size.

One of the most convincing proofs,

however, that this gas has considerable heat energy, as well as uniformity of quality, is the fact that it can be used satisfactorily for driving gas-engines. This is no mere opinion of mine, but a fact established by several careful trials made during the past two years, with some of the well-known "Otto" engines. At the Smoke Abatement Exhibition, recently held at South Kensington, my gas has been in daily use for about three months, to drive an "Otto" engine, working a Siemens dynamo-machine, and some Swan electric lights; and the fact that these lights have been uniformly steady is, I think, a good practical proof that the gas is suitable for engine purposes, and that the quality is constant. I may also mention that the English makers of these engines, Messrs. Crossley Bros., Limited, are so satisfied with the suitability and economy of this gas for their engines, that they are now laying down plant to work an aggregate of 200 h.p. with it.

The comparative explosive force of the two gases is as 3.4 to 1, *i.e.*, coal gas has 3.4 times more energy than the Dowson gas. But because the combustion of the carbonic oxide proceeds more slowly than that of the carburetted hydrogen gases, and because the diluents present in the cylinder affect the weaker gas more than the coal gas, in practice with an "Otto" engine, 5 volumes of the Dowson gas are used for one volume of coal gas. Allowing for this, the results of working some 3½ (nominal) h.p. engines have shown that about 110 cubic feet of the Dowson gas are required per indicated h.p. per hour, the indicator diagrams nearly resembling those obtained with coal gas. We have seen that 12 lbs. of anthracite produce 1,000 cubic feet of my gas, and that for the A size apparatus 100 cubic feet per hour are required to produce and superheat the steam used in the generator, so that with this size we have an effective production of 900 cubic feet from 12 lbs. of coal. From this, we see that the above trials, with quite a small engine, have proved that one h.p. indicated per hour is obtained with a consumption of gas derived from 1.46 lbs. of coal, after allowing for impurities and waste of the latter. The "Otto" engines of larger power consume less gas per h.p. than the small ones, and it is not unreasonable to suppose that the result of working the large engines now being prepared for my gas, will be a fuel consumption of very little over 1 lb. per indicated h.p. per hour.

The economical results are important, as you will see by referring to the following Tables, 4 and 5.

TABLE 4.

Working cost of steam engine indicating 35 horse power, for 2,500 hours (50 weeks of 50 hours each).

	£	s.	d.
Coal=35 h.p.×4 lbs.×2,500=156 2 tons at 15s.	117	3	0
Water at 2 gals. per indicated h.p. per hour=175,000 gals. at 9d. per 1,000.	6	11	3
Oil and waste at 5s. a week×50.	12	10	0
Wages of fireman at 21s. a week×50.	52	10	0
Repairs and depreciation, 15 per cent. on £380, price of engine and boiler fixed.	57	0	0
Interest, 5 per cent. on £380.	19	0	0
Total.	£264	14	3

$\frac{£264\ 14s.\ 3d.}{35\ h.p.}$ = £7 11s. 3d. per indicated h.p. per annum.

TABLE 5.

Working cost of "Otto" engine, with Dowson gas, indicating 35 h.p. for 2,500 hours (50 weeks of 50 hours each).

	£	s.	d.
Dowson gas required=18 cubic feet×5=90 cubic feet per indicated h.p. per hour ∴ total required=35 h.p.×90×2,500=7,875,000 cubic feet, and anthracite required for 7,875,000 cubic feet+allowance of 375,000 cubic feet for superheated steam=8,250×12 lbs.=44.2 tons at 15s.	33	3	0
Water for making gas, say 8,000 gals., at 9d. per 1,000.	0	6	0
Water for cooling engine.	0	10	0
Oil and waste at 5s. a week×50.	12	10	0
Wages of attendant to feed generator, at 10s. 6d. a week×50.	26	5	0
Repairs and depreciation, 10 per cent. on £390 and £170, price of engine and gas apparatus fixed.	56	0	0
Interest, 5 per cent., on £560.	28	0	0
Total.	£156	14	0

$\frac{£156\ 14s.\ 0d.}{35\ h.p.}$ = £4 9s. 6d. per indicated h.p. per annum.

In Table 4 I have given in detail the yearly cost of working a steam engine indicating 35 h.p., and consuming 4 lbs. coal per indicated h.p. per hour, the number of working hours being 50 weeks of 50 hours each. In Table 5, I

have given the yearly cost of working an Otto engine with my gas, during the same time, and indicating the same power. This mode of comparison is, to a certain extent, unfavorable to the gas engine; for, in practice, an engine has seldom the same load all day and every day, and, with this class of engine, the governor admits only the quantity of gas required for the actual power to be developed. The gas is in fact bottled up, so to speak, in the holder, and is admitted into the cylinder in the precise quantities required. With steam, however, the boiler fires cannot be regulated to suit exactly the varying power required. In practice, the average power may be taken as about one-third to one-half less than the maximum; but, without allowing for this in any way, and supposing that each engine is working up to a uniform power all the year, we find that the steam engine costs £264 14s. 3d., or £7 11s. 3d. per indicated h.p. per annum, and the gas engine, £156 14s., or £4 9s. 6d. per indicated h.p. per annum. This is an economy of over 40 per cent. in favor of the gas engine, when worked with my gas. Moreover, the saving in weight of coal in favor of the latter, compared with the steam engine is, as 44 to 156 tons = nearly 72 per cent.

I have shown you that this gas can be made very rapidly, and at very low cost, even when produced on a small scale. I have also shown you that it has a considerable heat energy, and that it cannot cause a soot deposit; and I have given you reliable data obtained with actual trials on gas engines. In fact, I have shown you its superiority and great economy, compared with coal gas, for all purposes of heating and motive power, and I think you will, therefore, agree with me, that for factories, large houses, and public institutions, it has many and great advantages.

For the supply of large towns many other considerations obtain, and there is no immediate probability of great changes being made by the companies who have the legalized monopoly of the pipe laying, and whose prosperous condition is against the making of radical changes. I think, however, it may interest you to have a few particulars relating to coal-gas manufacture, so that you may better appreciate the general bearings of the case. In the first place, I would refer you to Tables 6 and 7, which show the total cost of making and distributing gas for the four metropolitan and thirteen suburban gas companies.

TABLE 6.

Statistics of Four Metropolitan Gas Companies for 1880.

Selling price for 16-candle-power gas, per 1,000 cubic feet	s. 3.39
Total gas sold in year—about 18,091¼ million cubic feet.	
Gas sold per ton of coal carbonized—9,529 cubic feet.	
Coke made per ton of coal carbonized—44 bushels.	
Coke used for fuel—26 per cent. of make,	
Per 1,000 cubic feet sold.	d.
Cost of coals	18.43
Less residuals—Coke and breeze	5.58
Tar and products	3.59
Ammonia and products	2.86
	12.03
Net cost of coals	6.40
Manufacturing charges:—	
Purifying	.91
Salaries	.41
Wages (carborizing)	3.58
Wear and tear	4.93
	9.83
Working expenses:—	
Distribution	2.20
Rent and taxes	1.38
Management	1.30
Law charges	.11
Bad debts	.26
Public officers, &c.	.05
Depreciation of works on leasehold	.02
Other charges	.25
	5.57
Total net cost	21.80

Names of Companies.—Commercial Gas Light and Coke, London, and South Metropolitan.

TABLE 7.

Statistics of 13 Suburban Gas Companies for 1880.

Selling price for 14-candle-power gas per 1,000 cubic feet	s. 4.2
Total gas sold—about 2,310 million cubic feet.	
Gas sold per ton of coal carbonized—9,428 cubic feet.	
Coke made per ton of coal carbonized—46 bushels.	
Coke used for fuel—28 per cent. of make,	
Per 1,000 cubic feet sold	d.
Cost of coals	21.19

	d.	
Less residuals—Coke and breeze	6.97	
Tar and products	2.30	
Ammonia and products	2.07	
		11.34
Net cost of coals		9.85
Manufacturing charges:—		
Purifying	.96	
Salaries	.65	
Wages (carbonizing)	4.30	
Wear and tear	5.43	
		11.34
Working expenses:—		
Distribution	1.80	
Rent and taxes	1.91	
Management	3.21	
Law charges	.03	
Bad debts	.24	
Depreciation of works on leasehold	.21	
Other charges	.04	
		7.44
Total net cost		28.63

Names of Companies.—Barnet, Brentford, Bromley, Colney Hatch, Croydon, Crystal Palace, Lea Bridge, Mitcham, Richmond, Tottenham, Wandsworth, West Ham, and Woolwich.

These tables are based on Mr. Field's well-known and carfully compiled analyses of the metropolitan and suburban gas companies' accounts, and I have taken the last year for which these analyses have been published. I have purposely kept the four metropolitan companies separate, because they represent undertakings so huge that certain items of working cost are lower than where the manufacture is on a more moderate scale.

Taking Table 7, which gives the average of thirteen companies, we find that the total net cost of 1,000 cubic feet of 14 candle power gas sold was over 2s. 4½d., after allowing for the sale of residuals, and without including anything for dividends or interest on the capital outlay. We may then ask—"What probability is there of this cost being reduced by further improvements in the present system of gas making?"

I think we may assume that the items given under "working expenses" are not susceptible of much change, and we may as well confine our attention to the other headings. In the weight of coals, and in the wages for carbonizing, it is probable that some saving will be effected when cheap generator gas is used for heating the retorts, instead of the present coke fires. It is also possible that the prices realized for about half of the residuals, *i. e.*, for the tar and ammonia, may increase as new discoveries are made affecting their chemical treatment. But after fully allowing for these, we are then forced to the conclusion that, except in localities specially favored, there is no probability of large reductions being made in the present cost. We have, however, seen that there is a growing need for much cheaper gas for heating and motive power, and my own belief is that this need will not be satisfied until we have an abundant supply of gas for such purposes at 1s. per 1,000 cubic feet. To obtain this, however, I also think that the present system of gas making will have to be departed from.

At the meeting of the British Association of Gas Managers, held at Birmingham, in June, 1881, Dr. Siemens gave some interesting particulars of the varying candle power of the gas produced in ordinary retorts, at different stages of the process of distillation. He showed that, during the first and last stages, the gas given off was of inferior lighting power; and that, for about two-thirds of the whole period of distillation, between the first and last stages, the gas given off was of superior lighting power. From this, he argued, that the richer gas should be drawn off separately, and sold as lighting gas, and that the gas made during the first and last periods should be distributed and sold separately for heating purposes. It is with some diffidence that I venture to offer an opinion against so high an authority on these subjects; but I think it right to say that I see an insuperable practical difficulty in carrying out this suggestion. Such a system would depend on the consumption of the heating and lighting gases respectively following exactly the proportions in which each is produced, and how to effect this without serious trouble and complication in the storage and distribution, I fail to see. It was also urged in the discussion which followed, at the above meeting, that the companies would certainly sustain a loss if they continued to manufacture by their present method, and were to sell only two-thirds of their production as lighting gas, and one-third, at a much cheaper rate, as heating gas. Surely it would be

simpler and better to make separately, and in distinct apparatus, rich gas for lighting, and the cheapest possible gas, with coke and decomposed steam, for heating and motive power. The production of each kind of gas could then be easily regulated to suit the consumption.

It has further been suggested that when gas is made solely for heating purposes, it need not be purified at all, or very slightly; but I beg to protest strongly against the adoption of such a suggestion. Tables 6 and 7 show us that the cost of purifying gas for lighting is about one penny per 1,000 cubic feet sold, and such a small saving would never compensate for the loss due to the corrosion of metals and the injury to health which would inevitably follow the liberation of sulphur and ammonia compounds.

That gas for motive power will play a most important part in the future is, I think, beyond doubt; and in confirmation of the views I have expressed on this subject, I would remind you of two important statements which have recently received much public notice. In the first place, so high an authority as the Chairman in Council of this Society has told us in his inaugural address that "the average steam engines in use throughout the United Kingdom certainly do not give one twenty-fifth of the energy which may be taken as residing in the fuel they consume." He also referred to the excellent work done by gas engines, and remarked: "There are many temptations to the use of a good gas engine. There s no fear of the boiler blowing up, no fear of its being injured for lack of water, no stoking is needed, hardly any attention is necessary; and having regard to the great requirement for electrical illumination in clubs, theaters, and even in private houses, there appears to be a very large future for this kind of motor." Then Professor Ayrton has recently shown that the internally fired gas engine has a much higher theoretical efficiency than a steam or hot-air engine. He has, however, pointed out that a gas engine, burning illuminating gas, is in the same position as was, a few years ago, an electro motor for which, until quite recently, zinc was the fuel burnt for producing the electricity. In his remarks he said: "If it be possible to manufacture a cheap heat-giving gas, small gas engines driven with such gas, will not only surpass, in economy, steam engines of the same size, but will produce energy at a cheaper rate per horse power than the largest steam engines ever made."

It may be that the demand already existing for heating gas is not sufficient to warrant the gas companies in putting down separate mains, but I feel sure that the question is one of growing interest, and that gaseous fuel will, sooner or later, be one of the important factors in our industrial and domestic arrangements. The apparatus I have described to you this evening is already being used for several manufacturing and other purposes, and for motive power; and it remains to be seen how far the companies who supply gas to towns may find it to their advantage to adopt a modification of the process.

VOLTAIC ACCUMULATION.*

From "The Engineer."

We owe the term voltaic accumulation to M. Planté; we owe the idea of voltaic accumulation to him also. But more than this—we owe to Planté the rich results of a life devoted almost entirely to researches in connection with this subject. M. Planté employs the phrase voltaic accumulation in a double sense—to signify storage, and to signify cumulative effect. It is in this last sense that the term is generally used by M. Planté, and it is to voltaic accumulation in this sense that M. Planté has chiefly directed his attention. One of his principal aims has been to produce, by means of voltaic accumulation, the high tension effects usually obtained from the frictional electrical machine.

When the platinum terminals of a voltaic battery composed of a few cells are

* Abstract of a paper read by Mr. Swan before the Newcastle Chemical Society.

made to dip in acid water, gas in torrents pours upwards from them. If the same platinum poles, dipping in the same acid solution, be disconnected from the quietly but powerfully working battery, and put in connection with the prime conductor and the cushion of a large electrical machine of the frictional type, you may turn the handle by the hour and produce an amount of electricity that would maintain a continuous stream of fire, and yet not a single bubble of gas will rise from the poles. M. Planté makes a few cells—two are sufficient—do the work of charging secondary cells, which, after being charged, are joined in series and made to develop high tension effects. This is chiefly the kind of accumulation performed by M. Planté by means of his secondary cell, namely, the accumulation of tension or electro-motive force. The Planté cell consists of two plates of lead rolled together, but separated by narrow strips of gutta-percha. These two lead plates being, to begin with, in the same condition, generate no current when immersed in dilute acid and united through the wire of a galvanometer. But if the couple be for a time connected, the one plate with the anode and the other with the cathode of a voltaic cell, or any other form of electrical generator capable of developing an electromotive force of not less than three volts, the anode plate becomes coated with peroxide of lead. If, then, the secondary cell be detached from the primary cells it will be found to be capable of generating a powerful current of about one fifth more electromotive force than Grove's cell. When it is desired to obtain cumulative effects from a series of Planté's cells a mechanical arrangement is made whereby the plates of the different cells are so connected together that they are in effect one couple; that is to say, all the inner plates are connected together as one plate, and all the other plates are connected together as one plate. Arranged in this manner, if one of the poles of two Grove cells, coupled in series, be connected with the terminal which is common to all the inner plates, and the other pole be connected to the terminal common to all the outer plates, the same change takes place in the 100, or it may be the 1,000 cells as that which takes place in charging a single cell. That is to say, if all the outer plates were connected with the positive pole of the Grove cell, all these plates would be oxidized, and in this condition all the cells may be said to be charged, just as a Grove cell is charged when one puts the nitric acid into it; for the highly oxidized lead of a Planté cell plays exactly the same part as the nitric acid of a Grove cell, and it is also necessary to alter the connection of one cell with another, so as to connect them in series, in order to obtain from them the cumulative electromotive effect due to their number.

Planté has devised a convenient method of making this change in the connections. This apparatus illustrates the arrangement. The cells are arranged in line with a spring projecting upwards from each plate on each side of the line; between these two lines of springs an axle of ebonite runs, with metal bands so inlaid upon it, that when it is in one position all the springs on one side are pressing against a long strip of copper on that side, and all the other springs on a corresponding long string of copper on the other side. In this position the cells are arranged for charging, the two long strips of copper being the two poles. When charging has been effected it suffices to turn the ebonite bar on its axis through a quarter of a circle in order to disconnect the springs from the two long strips of metal mentioned, and to bring them into contact with short strips of copper inlaid and insulated in the bar and crossing it obliquely so as to put the oxidized or positive plate of one cell in metallic communication with the non-oxidized plate of the next cell throughout the entire series. The change of connections is the work of a moment, and the result is a muliplication of the electromotive force by the number of the cells.

M. Planté went a step beyond this. He charged a large series of plates of mica, partly coated on each side with tin foil, on the principle of the Leyden jar. These were connected in charging and in discharging in the same manner as the secondary battery, that is, all the coatings of tin foil turned one way were connected together, and all the coatings turned the other way were connected together. When, by the momentary joining of these two groups of

plate coatings to the two poles of 800 secondary cells, the plates became charged, the connections were then changed from quantity to tension. By this contrivance the electromotive force of the four volts, due to the two primary Grove cells, was accumulated first to 1,800 volts, and this again was increased fifty fold by the mica plates. I can bear witness to the fact that it was sufficient to produce flashing discharges some inches in length, exactly resembling the discharges of a frictional electrical machine. That is electrical accumulation in one sense, but there is another sense in which the phrase has been much used of late in connection with Faure's accumulator, namely, in the sense of storage. Planté's cell, with slight modifications, lends itself most perfectly to voltaic accumulation in the sense of storage. The very essence of the idea of storage is retentivity. The cell to act as a reservoir or store must be retentive of the charge communicated to it. This is a quality possessed in an eminent degree by the Planté cell. There is, comparatively with other voltaic cells which, but for the want of retentivity, might be employed for electrical storage, very little loss of charge by lapse of time within the limit of a few hours. But for the defect of loss of charge by local action—that is, chemical action not utilizable in the production of electric currents, the zinc and copper cell of Daniell and several other well-known voltaic combinations, not usually regarded as susceptible of being used as secondary cells, might have been employed for electrical storage. Perhaps the ideal of a cell for storage is Grove's gas cell. Here is a specimen of it; it consists of two gas tubes, and two plates of platinized platinum immersed in dilute sulphuric acid. If, while the tubes are filled with dilute acid, one plate is connected with the positive and the other with the negative pole of a voltaic battery, the one tube becomes filled with oxygen and the other with hydrogen, and when so filled the cell is an electric store capable, even after the lapse of a long time, of yielding a current. But Grove's cell is quite out of the question for large operations, if only because plantinum is so scarce. Theoretically it would perhaps be improved by making the hydrogen pole of palladium instead of platinum, so as to obtain the advantage of greater condensation of the hydrogen, and thus to reduce the resistance by increasing the extent of the contact between the gases, the pole plates, and the acidified water. Dr. C. W. Siemens communicated to the York meeting of the British Association some interesting experiments in the employment of plates of carbon, both simple and platinized, as substitutes for platinum plates in the construction of a gas battery. The porosity of the carbon plates was utilized so as to bring the poles close together and greatly reduce resistance. The results obtained were well worthy of publication, although they did not quite reach the point aimed at, namely, practical utility for the electrical storage of energy. For electrical storage on any large scale we look in vain to discover a better material than that fixed upon after infinite painstaking by M. Planté. Planté's cell, pure and simple, is a most admirable electrical accumulator in the storage sense of the word. It has one drawback, however: it requires a considerable time to give to the lead plates a large storage capacity.. M. Planté's method of preparing his cell is as follows:

The secondary cell is first filled with water acidulated with sulphuric acid—1 quart acid to 10 quarts of water—and on the first day it is charged by the current from two Bunsen cells six or eight times, the direction of the primary current being changed at each new charge. The secondary cell is discharged between each reversal of the direction, and it is ascertained either by heating a piece of platinum wire to incandescence, or by other suitable means, that the duration of the secondary current continually increases after each charge. The time during which the secondary couple is submitted to the action of the primary current in the same direction is increased little by little. Thus, on the first day the period is increased from a quarter of an hour to half an hour, and one hour; and, finally, the battery is left over night in the process of charging. The next day it is discharged, and then recharged for two hours in the opposite direction, then again in the previous one, and so on. But soon a limit is reached, beyond which the duration of the secondary cur-

rent is not found sensibly to increase, especially when the primary cells, not having been removed, have grown by these successive actions little by little weaker, and have no longer sufficient intensity to cause the electrolysis to penetrate deeper into the interior of the lead plates. The secondary couple is then left at rest for eight days, and at the end of that time is recharged in the opposite direction for several hours continuously, without making on that day a fresh alteration in the direction of the primary current. Then the interval of rest is extended little by little to a fortnight, one month, two months, &c., and the duration of the discharge is found to go on continually increasing. It has, in fact, no other limit than the thickness of the lead plates. The positive plate, if it is thin, finishes by being almost entirely transformed by time into peroxide of lead of a crystalline texture; and the negative plate becomes formed by degrees, to a certain depth below its surface, of reduced lead of a granular and crystalline nature. It is not always necessary to push the electrochemical preparations of secondary couples as far as this complete transformation of the physical and chemical nature of the plates, for the couples would ultimately acquire a much greater resistance and take more time to charge them. When the couples yield a current of sufficient duration for the purposes for which one wants them, it is no longer necessary to change the direction of the primary current each time the cells are charged. The quantity of peroxide of lead accumulated upon the positive plate would take too long to reduce, and no result would be got from the couple before several hours. A definite direction is therefore adopted, in which the secondary cells, when once sufficiently "formed," are always charged.

It is evidently desirable—more especially in view of the want more and more urgently felt as time goes on, of an accumulator which will be available for the large and important uses to which electricity will in future time be put—if possible to avoid this tedious process of preparation so minutely described by M. Planté. No doubt it answers the purpose quite well when industrial applications are not in question, but for electrical accumulators such as must be used in connection with a central system of electric lighting, and which would probably involve the use of a set of large cells in every house, this slow process of preparation would be hardly applicable. It was with a desire to avoid this disadvantage and give to Planté's cells a greater capacity of storage that I made the experiments last winter, the outcome of which was the modification of Planté's cell, which I showed you at our February meeting. Here are some of the cells I then exhibited in action. The idea of this modification was to increase the surface of the lead by means of lead foil, crimped and formed into frills, the interstices between the frillings being filled with electrolytically deposited spongy lead. The same idea has been applied in a somewhat different way by M. Faure in his accumulator. In M. Faure's accumulator red lead, mixed with dilute sulphuric acid, is plastered on lead plates, the coated plates are wrapped in felt, and either rolled up like the plates of a Planté cell or doubled together and placed in rectangular lead-lined wooden boxes. These cells have been made on a large scale, and for this reason, and because the application of the red lead coating greatly favors the obtaining of storage capacity, effects have been obtained from them clearly pointing to practical use in electric lighting, and perhaps also for other purposes. The cell has, of course, the same electro-motive force as the Planté cell, of which it is a modification; being large, it has, when fully charged, a small resistance, and is, on that account, capable of producing astonishing effects in the way of heating thick wire. [The lecturer heats some wire.] Thirty of these cells, weighing about 50 lbs. each, when properly charged, will keep twenty of my lamps up to 20-candle power for several hours. M. de Meritens has also made an accumulator on the Planté lines.

I have recently introduced into the construction of the Planté cell some modifications which, I anticipate, will increase its utility when applied on a large scale for the practical work of storage for electric lighting. One of my innovations consists in making the lead plates corrugated or cellular, the cells or grooves being filled with spongy lead, which

from the form of the plate will remain attached to it without any external wrapping of felt or similar material being necessary. The felt in the Faure cell must, I imagine, be in a short space of time destroyed by the action of the acid, and occasion displacement of the material applied to the surface of the plate, and held in its position by it. I have heard that it is proposed to substitute asbestos cloth for the felt; this, no doubt, will remedy the defect I have mentioned, but it must greatly increase the cost of constructing the cell. It is obviously desirable to avoid the use of any extraneous material, and the use of grooves or cellular plates accomplishes this object. I have made other improvements for the means of obtaining electrical storage, details of which I must for the present hold in reserve, but with the hope at some future time of bringing them under the notice of the society.

THE ANALYSIS OF POTABLE WATER.

By Mr. CHAS. W. FOLKARD.

A Paper read before the Institution of Civil Engineers.

From "Iron."

In the first place, the author reviewed the present state of analytical chemistry, the conclusion being that, as far as mineral substances were concerned, the existing methods were nearly perfect. But when organic analysis was considered, a different state of things was apparent, owing to the great number, complexity of structure, and unstable nature of many organic bodies, especially those contained in the secretions and tissues of plants and animals, in addition to which organic matter was present in drinking water in very small quantities, and always more or less mixed with other substances.

The subject might be divided into four parts:—(1) The various ways in which water became contaminated; (2) the methods employed by analysts to detect and determine the extent of this contamination, with an opinion as to the probable value of these methods; (3) the bearing of the results of biological and microscopical investigations on the subject; (4) the utility of irrigations, chemical treatment and filtration, for purifying purposes.

Under the first of these heads, the normal constituents of rain water were considered, all of which were practically harmless, so that rain water, as it fell on the earth, or on the gathering grounds of a system of water supply for a town, was unobjectionable, having contracted but an inappreciable amount of contamination. Spring water was not so pure, owing to its percolation through strata from which various mineral substances were dissolved. River water was the most objectionable, on account of the enormous quantities of animal and vegetable contamination which it acquired. Lastly, well water varied greatly in quality, in some cases being excellent where the wells were deep and surface water was excluded, or when the district was thinly peopled; in other instances well water was more contaminated than river water, as in shallow wells in towns.

Under the second heading, the author pointed out that analytical chemists had hitherto been compelled to be content with the examination of the products of decomposition, or with the determination of one or two constituent elements of the organic impurities of water. Unfortunately, the products of decomposition of the organic matter in water were the same as the normal constituents of rain, viz., carbonic acid, ammonia, and nitric acid. It was therefore impossible to ascertain whether those substances were derived from contaminating bodies or had been dissolved by the rain in falling.

The various processes of water analysis were then considered. In the first and oldest method a measured quantity of water was evaporated, and the residue was subjected to a red heat in a platinum dish. By this treatment the animal and

vegetable substances were burnt away, and from the loss of weight, the amount of organic matter was inferred. One great objection to this and the following process was the evaporation of the water. With such unstable bodies it was by no means improbable that a large portion was destroyed during the process. By the second method, the solid matter, left after evaporation of a known quantity of the water, was mixed with an oxidizing agent, and heated to redness in a glass tube. The carbon and nitrogen of the organic matters in the residue were obtained in the form of carbonic acid and nitrogen gases, from which were deduced the weight of carbon and of nitrogen present as organic matter in the residue. This ratio of carbon to nitrogen did not, however, afford the slightest clue to the identity of the organic matter. It might be intensely poisonous or dangerous, or, on the other hand, harmless.

The albumenoid-ammonia method consisted in boiling the water with an alkaline oxidizing agent, by which the organic matter was decomposed, and part of its nitrogen evolved in the form of ammonia. This had the great advantage of simplicity of manipulation, and was not open to the objection that previous evaporation was required.

The last considered was the permanganate method. In this the index of impurity was the amount of oxidizing agent —namely, permanganate of potash, required to destroy the organic matter in the water. Inasmuch, however, as no relation had been established between the oxidability of a body and its action on the animal economy, this method would not afford reliable evidence of the fitness of a sample of water for drinking purposes or the reverse.

Under these circumstances the conclusion seemed inevitable, that the subject was as yet beyond the power of the analytical chemist.

It was, however, possible, by the second method, to determine approximately the minimum amount of contamination which had taken place since the water was precipitated as rain. For this purpose the whole of the nitrogen existing in the water was estimated, and the average amount in rain falling on the surface of the earth deducted. The remainder was due to animal and vegetable contamination, and it has been found convenient to express it in parts of average London sewage; that was to say, the sample was returned, as having been contaminated to the same extent as if pure rain water had been mixed with so many parts of ordinary sewage. But this afforded no direct evidence as to its fitness for dietetic purposes, becauses ubsequent oxidation and fermentation might have rendered the water to a great extent harmless

The author next considered the bearing of biological research on the subject, pointing out that mere dilution had an almost inappreciable effect in disarming the germs of disease of their power. Thus, supposing a glass of water to contain but one germ, if the person taking it was sufficiently unhealthy or weakly, he would contract the disease almost as certainly as if there were hundreds of germs. In the author's opinion it would be impossible to banish zymotic disease from towns, the water supply of which contained the dejecta of persons suffering from the disease, even though present in the most minute quantity. The very weakly would contract the complaint from the water, and from them it would spread to the more robust around them. Again, these germs were endowed with such persistent vitality, that they withstood the effects of heat and cold, moisture, drought and chemical agents to an almost incredible extent, affording what seemed, at first sight, indisputable evidence of the now exploded doctrine of spontaneous generation. From this it appeared that once-contaminated water was unsuitable for dietetic purposes.

In conclusion, the author contended that a radical change was the only remedy. Irrigation and chemical treatment were alike powerless; in addition to which, during heavy rain all existing sewerage systems were incapable of dealing with the huge volumes of water poured into them, and the sewage was allowed to flow direct into the river, to the manifest disadvantage of the towns below, who were dependent upon it for their water supply. Filtration, again, was powerless to effect real purification. The germs of disease were so minute that they could pass one hundred abreast through the interstitial spaces of ordinary sand, and dissolved substances

were, of course, unacted upon. In view of the great increase in cancerous diseases of the stomach and intestines, the subject was worthy of the most careful study, and taking into consideration the unreliability of the results afforded by chemical analysis, the only way to ascertain if a sample of water was fit for drinking purposes was, in the author's opinion, to trace it to its source, and see that contaminating matter was excluded from the time that the water fell as rain till it entered the reservoir or engine well.

TELEMETERS.

By LIEUTENANT A. H. RUSSELL, U.S.A.

A Paper read before the Society of Arts, Boston.

THE object to be accomplished by the use of these instruments is the determination of the distance of an inaccessible object. This is done by measuring the base and two adjacent angles of a triangle. The instruments used vary greatly in construction; that of Berdan, weighing 2000 pounds and costing $5000, has a fixed base of four meters length, and is provided at each end of this base with a telescope, one of these telescopes being set at a fixed angle with the base, and the other capable of being rotated on its axis. The angle made by the line of collimation of the fixed telescope with the base is usually a right angle. The instrument is carried on a two or four-wheeled carriage made for the purpose.

On the other hand, some of these instruments are small enough to be carried in the vest pocket.

He then read an extract from a recent letter by General E. Vray to the London *Times*, to show the importance of the use of telemeters. As will be seen from the following descriptions, the greatest obstacle to the general adoption of range finders is the considerable degree of complexity in their construction, and consequently in their method of use. To use these forms requires skill and a considerable degree of intelligence and information upon the part of the operator. A simple form of instrument readily used by the average non-commissioned officer is required before one can be generally adopted.

Lieut. Russell next divided telemeters into three classes, viz., acoustic telemeters, stadia, and topographical telemeters,—the first depending on the velocity of sound, and the second determining the distance by reference to the apparent height of an object whose real height is assumed to be known.

In regard to the third class, viz., that of topographical telemeters, he said:

As in telemetry, only one side of the triangle to be solved can be known, the problem always reduces to the measurement of a base and two angles. Three cases occur: 1st, the base may be assumed, and the two adjacent angles measured, to fix the direction of the object from the two extremities of the base; 2d, the length of base with one angle at the base can be assumed, and one of the two other angles of the triangle measured; or, 3d, two angles can be assumed, and the length of the base sought, from whose extremities the object can be seen under these two angles; or, in other words, the length of base which subtends the third angle has to be determined.

There are, therefore, three kinds of telemeters, viz.,—

1st, telemeters for variable angles; 2d, telemeters for a variable parallax; 3d, telemeters for a variable base.

Of the first, we know only that of Capt. Nolan of the English army, which effects directly the solution of any triangle whatever.

It measures the two angles at the base, each of which differs only two or three degrees from a right angle.

Two observers are required, furnished with instruments just alike, for working simultaneously at the two extremities of the base.

To determine the distance required in a rapid manner, Capt. Nolan has devised a sort of calculating reel of cylindrical form.

The apparatus complete is composed of the two instruments, of the reckoning cylinder, and of a tape for measuring the length of the base, which varies generally from forty to seventy yards.

Of the second class he enumerated the following, viz., those of Dupuy de Podio, Goulier, Gautier, Klockner, Mariage, Lobbez, Gaumet, and Caillot,—all of which measure the parallax, the right angle and the base being known; also those of Stubendorf, Paschnitz, and Plebani, which measure a segment of the hypothenuse, the right angle and the mean proportional being known.

Of the third class he enumerated (*a*) those of Bauernfeind and Azémar, Nos. 1 and 2, which measure the base, the two angles at the base being known; (*b*) those of Gautier, Bousson, Lobbez, Gaumet, De Roksandik, and Azémar, No. 3, which measure a base, the angle at the base and the angle at the vertex being known; (*c*) that of Bousson, which measures a segment of the hypothenuse, the right angle and the parallax being known.

After a brief description of each instrument he said: Upon the whole, the telemeters used with a variable base have, over those for a variable parallax, the advantage of more simple construction and freedom from all mechanism; they are, therefore, less costly, and less subject to the derangement to which field instruments are exposed. Moreover, they are susceptible of a closer approximation, because the lengths that they measure are directly proportional to the distances; while with other telemeters the angles, or the lengths which represent them, are inversely proportional to the distance. On the other hand, they involve some fumbling about and repetition to fix the angles, which render the operation rather too long, and they often require the measurement of rather long bases, not easily laid off in all localities.

He next divided telemeters into single-station telemeters, or those that carry on the instrument a fixed base, and where the observer has no need to move; and double-station telemeters, where the observer has to take one observation from each station; and said that single-station telemeters are, as yet, far from being suited to field service, and that we must wait before thinking of using them with the army till they have undergone some improvements which science cannot predict. Passing, then, to a consideration of double-station telemeters, he said that the methods of using them reduce in practice to the three following operations:

1st. Laying off a direction which makes a fixed angle, 90° or nearly 90°, with the line to be measured.

2d. Measuring a base in this direction.

3d. Measuring an angle, usually very small, or a length equally small at the extremity of this base.

The first operation is common to all the telemeters. The two others are sometimes combined, so that one of them seems to be suppressed. These telemeters he divided into the following four classes:

1st. Telemeters with crossed telescopes or alidades, among which he enumerated those of Nolan, Dupuy de Podio, Mariage, and Caillot.

2d. Single-reflection telemeters, among which he enumerated, (*a*) those with one mirror, viz., those of Paschnitz, D'Azémar No. 1; and Bousson Porro; (*b*) those with two divergent mirrors, viz., that of D'Azémar No. 2.

3d. Double-reflection telemeters, (*a*) those with two convergent mirrors, viz., those of Gautier, Lobbez, Gaumet, De Roksandik, and Watkins; (*b*) those with three mirrors, viz., those of Bousson and D'Azémar No. 3; (*c*) those with four mirrors, viz., that of Klockner.

4th. Prison telemeters, among which he enumerated those of Goulier, Stubendorf, Plebani, D'Azémar No. 4, Bauernfeind, and similar to this is the Weldon range-finder.

In all the single-reflection telemeters, whether there are one or two mirrors, an angle is laid off by means of the principle that the angle made by the reflected ray of the mirror is equal to that made by the incident ray, and thus, by suitably adjusting the mirror or mirrors, any desired angle can be laid off.

The chief objection to this class of instruments is that the singly-reflected image is very unstable, and any tremulousness of the hand holding the instrument, or any error in the position in which it is held, will cause quite a large

error in the distance to be estimated; in other words, the instability of position of the image is a serious objection to their use.

On the other hand, double-reflection telemeters depend for their action on the principle that, when a ray undergoes double reflection from two mirrors, without leaving the plane perpendicular to these two mirrors, the angle formed by the incident ray with the reflected ray is twice the angle of the mirrors. With this arrangement it is evident that the deviation is not changed by the movement of the instrument, so that the principal cause of the instability of the images in the single-reflection telemeters is obviated in the double-reflection instruments. The fixed line of sight might, therefore, be dispensed with, and the mirrors arranged on a plate without enclosing them in a tube, and without eye piece or lateral opening, for it matters little in what part of the mirror one looks. In this case we are exposed to another kind of error; since the steadiness of the image and the constancy of the angle are subject to the condition that the plane of sight, that is the plane fixed by the eye, the mark and the image, shall be perpendicular to the intersection of the mirrors; or, in other words, parallel to the plate carrying the mirrors.

After discussing at some length the double-reflection telemeters constructed with mirrors, he passed to a consideration of prism telemeters. In these instruments two of the faces of the prism serve the purpose of two mirrors inclined at an angle to each other, and the double reflection from these faces makes, with the incident ray, an angle equal to twice the angle these two faces make with each other; moreover, by the use of prisms we obviate the difficulty of having a double image, one reflected from the glass and one from the silvered surface; and also much less light is lost than by the use of mirrors.

One form of the Weldon range finder is a simple glass prism, with two of the faces inclined at such an angle that we should be able to lay off with it an angle of 88° 34′ 3″; for an isosceles triangle, with this for each of the angles at the base, has its sides twenty times the base, hence, if we construct, by the use of such a prism, an isosceles triangle on the ground, whose vertex is at the object whose distance is to be measured, and measure its base, the distance of the inaccessible object will be found by multiplying the base by twenty. In a prism made in London, and sent with a copy of a paper read before the Royal Artillery Institution, by Major J. B. Richardson, and furnished from the ordinance office, the larger angle of the prism was 88° 34′ 3″. This, of course, would not enable us to lay off this angle itself. For this purpose it is necessary that two of the faces should be inclined to each other at an angle of one-half that amount, or 44° 17′ 1.5″. A prism with this angle was made by Mr. Alvan Clark for Lieut. Russell at a cost of $12, but he estimated that they could be supplied in quantity at $2 each.

There was also some difficulty in grinding them accurately to the required angle, but this defect would be removed were a large number required.

Another form of the instrument consists of two mirrors set at an angle of 44° 17′ 1.5″, and this gives similar results.

The first of these instruments involves the same principle as the prisms of Max Bauernfeind, which he has advised for surveying purposes, and which, he says, might be so constructed as to serve for range finders.

The chief difficulties to be met with in the use of such an instrument are the following two: First, when we attempt to lay off an isosceles triangle with fixed angles at the base, it is often difficult, and may be impossible, to find a point at the other end of the base from which the desired object can be seen. In order to overcome this difficulty, it is desirable to be able to have a choice of more than one base; hence, a prism with which we can lay off more than one angle is a desideratum. For this purpose Lieut. Russell proposed to modify Max Bauernfeind's five-sided prism in such a way as to enable one to lay off two different angles by using different faces of the prisms.

It is convenient also to be able to lay off a right angle, and for this purpose two of the faces should be inclined to each other at 45°.

The second difficulty is that, if the observer is to use for both of the base angles of the isosceles triangle the same sides of the prism, he is obliged to move

backwards along the base of the triangle. Hence, another improvement is to have a prism by using two faces of which an an angle of a little less than 90° can be laid off, and by using two other faces an angle equal to the supplement of this can be constructed. Whatever the angles at the base be, when the angle of the faces is fixed there is a constant ratio between the side of the isosceles triangle required and the base; and hence, having measured the base, it is only necessary to multiply it by this number to obtain the required distance. In this connection, Lieut. Russell exhibited two pocket-surveying instruments which had been loaned for the occasion by Messrs. Keuffel & Esser, of New York. One of these instruments was an optical square, consisting of two mirrors set at an angle of 45° to each other, thus enabling the observer to lay off a right angle. By setting the mirrors at 44° 17′ 1.5″ instead of 45°, we should have the means of laying off an angle of 88° 34′ 3″, the angle desired in the Weldon range finder.

The instrument consisted of two prisms set across each other, having angles of 22½°, 45°. and 112½°, this instrument enabling us to lay off angles of 45° and 90°. By altering again the angles of the prism we should have the angle required in the Weldon range finder.

Prof. Lanza, of the Institute of Technology, was the next speaker. He said: Through the kindness of Messrs. Keuffel & Esser, of New York, we have before us two pocket-surveying instruments just shown us by Lieut. Russell. These instruments belong to a class which have not been much used in this country, but which, on account of their small size and lightness, are useful in detail work, where very great accuracy is not required.

The optical square, as has been shown, enables the observer to lay off a right angle, and as this angle is laid off by using the double reflection of the object, there is no instability of the image. Another instrument, and one which is due to Max Bauernfeind, is what is called the Prismenkreuz. It consists of two 45° and 90° triangular prisms placed one over the other in such a way that the hypothenuses cross each other at right angles. Looking into the lower prism, we obtain by double reflection the image of an object, the line joining which with the prism is at right angles to our line of sight; looking directly above, into the upper prism, we obtain the image of an object on the prolongation of this line, and looking directly above these over the prisms we look along a line perpendicular to the above-mentioned line. In short, the Prismenkreuz enables us to lay off angles of 90° and 180°, and it enables us, therefore, to solve all surveying problems which depend for their solution on the construction of these angles.

The cross prism as made by Max Bauernfiend could be employed for the same purposes by using the single reflections; but as these are unstable images it is much more conducive to accuracy to use the double reflections; and as these last are always somewhat fainter than the former, it is sometimes a little difficult to see the doubly-reflected image in the presence of the bright single reflection. This difficulty might be obviated, however, by determining the points of the prism faces where the incident rays are to enter the prism, and where the reflected rays are to emerge, and covering up all other parts of the faces of the prisms. This also gets rid of the reflections from the outer faces. I have not here one of these instruments as they are described by Max Bauernfeind, but through the kindness of Prof. Cross, I have had two 45° prisms mounted in the same manner as in the Prismenkreuz. To get rid of the single reflection in these prisms, I have determined these points and covered the remainder of the prisms with paper.

In a conversation with Lieutenant Russell on this subject, it seemed to us that some advantage would be gained by placing the prisms across each other in a different manner, viz., placing the two hypothenuses parallel to each other, with the vertex of each right angle at the middle of the hypothenuse of the other prism, as this, we think, would enable the observer more readily to avoid confounding the single-reflection and the double-reflection images.

The second instrument, loaned by Messrs. Keuffel & Esser consists was, as stated, of two prisms, each of which has angles of 22½°, 45°, and 112½°, one prism over the other, with the two longest sides in the same plane.

This enables us, as was stated, to lay

out angles of 45° and 90°, and hence to solve all those surveying problems that depend on this for their solution.

In addition to the above-described instruments, Max Bauernfeind has devised some four and five-sided prisms for laying angles of 90° and 180°, and he states that prisms with suitably cut angles might be used as range finders, but does not describe any special arrangement for that purpose. It seems to me that these instruments are deserving of the attention of the Society, as furnishing the means of doing some surveying work, where great accuracy is not required, by means of small pocket instruments, instead of by the use of a heavy transit or theodolite.

FOUNDATIONS.

By Mr. WILLIAM C. STREET, A.R.I.B.A.

A Paper read before the Civil and Mechanical Engineers' Society.

In bringing this subject forward as a topic of discussion, I would claim that it merits the earnest attention of both engineer and architect. It is often taken as too much a matter of course, and in consequence some of our greatest efforts in construction are brought to grief, and that by the neglect of what is obviously the first essential of all good building; while on the other hand sometimes the most creditable and successful part of our work, and what has cost us most thought and care, is hidden from view, and its importance quite unappreciated, especially by those long-necked geese, who would be most sapient and loudest in condemnation if anything were to go amiss.

I shall not hope to exhaust the subject in a short paper, and not having had experience in every kind of foundation, it is to be desired that you will in the discussion not only attack the paper for what it contains, but also for what it omits. By that means the author will be a gainer as well as yourselves. It were almost needless to say that before dealing with any particular foundation, it would be well to consider and calculate the weight of the wall or work we are going to place upon it, and also whether it will be a steady weight or one subject to vibration.* Almost every substance in nature is capable of supporting some other substance or weight, and given a capacity of sustentation, if ever so little per square foot, it is a simple sum to determine how many square feet will be required to take in absolute safety the weight transmitted. By distributing the weight over a sufficiently large area, almost any soil may therefore be safely built upon, provided that its conditions are of a permanent character. This question of constancy is one requiring more than ordinary forethought. Of course, there are cases in which no one could foresee what was subsequently to take place. I know, for instance, of two churches in the London district which were threatened with destruction by the construction of railways in their vicinity. One is in the south-eastern or Bermondsey district, and many years ago, during the construction of one of the viaducts carrying the Greenwich railway, the contractor opened a large extent of deep foundations, which had to be kept clear of water by incessant pumping. This, of course, underdrained and contracted or lowered the ground in the locality, and several alarming cracks made their appearance in the building. A great outcry was raised by the parochial authorities, and the railway company was threatened with heavy damages, but by judicious procrastination on the part of their agents the dispute was deferred until after the completion of the work, when, the pumping having ceased, the level of the water in the soil gradually rose to its former height, and the cracks nearly closed again, so that, by the aid of neat pointing, the permanent damage was but slight. In the second case, the church was built with quite adequate and apparently deep enough foundations; but seven or eight years afterwards a suburban railway is constructed, passing here in

* The weight imposed on the footings of an ordinary London House, say 50 feet high, with four floors all loaded, is perhaps about 7 tons per square foot, while in St. Paul's Cathedral the greatest strain is 14 tons per square foot.

a cutting over twenty feet below them, and only a few yards off. In this case, the drainage was, of course, permanently lowered, and the eastern end of the church, that nearest the line, showed a decided inclination to part company with the nave. The architect, of course, advised that the right thing to be done, was to underpin to a sufficient depth to insure permanent stability. This heroic and costly sort of procedure was objected to by the penuriously-minded; and one of the churchwardens, a votary of modern science, bethought himself of a cunning worker in metals, who took the matter in hand, and has tied together the ruptured parts in an economic manner with iron bands. Up to the present this has sufficed. I only hope that what was the weaker member may not ultimately pull the stronger with it to destruction, and I would sooner have contributed to good masonry underpinning than to this ingenious artifice. Also, in the case of the destruction of several shops and houses in the Seven Sisters Road about two years since, the disaster was, I believe, clearly proved to have been occasioned by the disturbance of the ground at a dangerous depth close to them for the formation of a sewer, just after they had been erected, and when everything was green and unset. It is, therefore, always wise to carefully consider what possible, if not probable, alterations may take place, altering the condition of the substratum or foundation from that in which it is when you build. I will now proceed to notice several different kinds of foundations, and, so far as I know, the best manner of dealing with them.

Peat Foundations.—In some soils, such as peat, it is often practically impossible to carry your walls down to a sufficient depth to meet with a solid base or foundation, and in such cases you have three courses open to you, either to found on a strong concrete floor spread over a sufficient area, or to use piles, or to use cylinders of iron or brick. If the first course is determined on, you should not only carry your floor all over the surface to be occupied by your buildings, and see that it is constructed so as to be thoroughly sound and homogenous, but take care that the edges extend well beyond the footings of your walls. I believe that the cracks and settlements in buildings, with which I was connected as clerk of works, and constructed on such a foundation, were entirely due to very heavy walls coming close on to the edge of the concrete floor, causing it to buckle and crack, and to settle irregularly as weighted by walls of unequal thickness, &c. Another characteristic of this settlement was the gradual and continued settlement of the heavy corners, and I think the French system of forming a lip on the under side of the edge is a good one, as it tends to keep the substratum within its limits, and makes the concrete floor or foundation into a kind of inverted tray. I consider that the material of your foundations cannot be too strong and homegeneous, but with regard to the superstructure, I would prefer a coursed and bounded or articulated construction, that would, if necessary, yield slightly at the joints and accommodate itself, without fracture, to any slight or unequal settlements during construction. This is the more necessary when the foundation to be got is not of the best. I need hardly refer to the description of concrete to be used in such cases, as that is a subject exhaustively treated of elsewhere. I may mention, however, that though you may make lime mortar too fat, and get a bad mortar at a great expense, you can hardly make your Portland cement concrete too fat. I have heard of concrete being made of remarkably weak proportions, but about 1 of cement to 8 of gravel, broken stone, or ballast, is probably little enough; and I would also recommend everybody using Portland cement to test the strength of each delivery, as it is only by that means they can be sure of the strength of their concrete. In the case of some buildings close to where we now are, they also are floating on peat, and this precarious condition was, I fear, aggravated by putting in the foundations in small sections, and with indifferent concrete. The consulting engineers who were called in deprecated underpinning, and built a retaining wall of concrete on the eastern side, and concrete inverts to some of the basement chambers; but I am greatly deceived if the buildings have not continued settling since this was done, about May, 1878. The Admiralty buildings, at Whitehall, are built on timber piles, and apparently with great success,

for I do not remember having noticed any particular settlement about the building. That the ground in that locality is sufficiently lively I can personally testify, for the passage of a two-wheeled cart would make a room in Whitehall Place, in which I used to work, vibrate so much as to frighten those who were unused to it.

Sand Foundations. — In founding work on running sand the utmost care and consideration are needed. I have known one length of wall to be undermined by the pumping out of the sand with the water when putting in the foundations for the next length. The only way in such a case is to make your concrete floor the entire width of your trench and put it in as rapidly as possible, to seal the sides of the trench as well as you can, and to pump out what water comes in from the level of the top of the concrete and not from a sump. In the case of dock works founded on running sand, it is also necessary to consider what, if any, will be the effect produced when the pumping operations necessary during construction are brought to a termination, and the water allowed to exert a varying pressure on the floor of the dock and the foundations of the walls, in accordance with the variations of tide level outside the dock. It is open to us all to be very wise after an occurrence has taken place, in which, perhaps, had we had the direction of matters we should not have done nearly so well as those upon whom the misfortune fell, and in indicating in any case how matters might be improved upon, as seen by the light of what has happened, I do so with all humility, and do not for a moment pretend I should have foreseen or prevented the past. In a recent notorious case the damage to the works did not happen until after their completion, when the water being admitted to and constantly retained in the interior at the level of high water, the pressure downwards and outwards at low water was such that it forced itself through the sandy floor and under and along the line of the lock walls out into the river, sucking with it such immense quantities of silt or running sand as to cause a general undermining and ruin of the dock works. There was, of course, a similar varying pressure inwards from the river during the construction of the works, but the dam at the entrance kept this sufficiently far off to prevent ill effects; when, however, this dam was removed and the distance reduced, the effect of similar pressures outwards was so much greater that in a few weeks the underground passage was established and the catastrophe occasioned. It would not perhaps have happened had the pile apron across the mouth of the lock on the river, or dockside, been driven to a greater depth and sufficiently close and tight together, so as to retard the subterranean flow of water and sand. Apparently only a very little extra force, one way or other, was sufficient to turn the balance from safety to danger. The most eminent engineering advice has been taken with regard to the reconstruction, and the author is unacquainted with the measures proposed; but in his opinion it would be better in such a case that the lock should be longer, and thereby the distance increased between the river and the floor of the dock; also that right across the mouth of the lock, at both river and dock end, two rows of either wood or iron sheet piles should be driven as deep as possible, and the sand between them excavated for some depth and the space filled in with good clay puddle, so as to form two watertight underground walls at each end, and sufficiently remote from each other not to occasion danger. Further, the floor of the dock might be covered with a good layer of clay puddle, as you would do if you were making a reservoir to hold water for supplying towns; and I do not know that engineers have any reason for altering this practice when you build a reservoir to hold water and ships, if the natural foundations are not water tight. While speaking of the narrow line between safety and danger, and insisting upon always being on the right side, I would mention the opposite argument taken by an engineer to a Scotch dock not long since. In the carrying out of the work there was a slight mishap, and being remonstrated with by one of the commissioners, the engineer claimed that it proved his ability, because he could well have made the dock cost double the money and then been safe; but he had so designed the work that it was successful, except a slight accident, for little

more than half the amount he said a less courageous man would have caused them to expend. Such reasoning can, as has been seen, be followed with disastrous results, and as the foundations are only a small portion of the expense, but the principal portion so far as stability is concerned, you cannot be too safe there.

With regard to foundations for bridges or piers, on or across sands, the usual plan now is to sink iron tubes or piles, with large disc or screw shoes or feet to them, as, by making these feet of suitable diameter, you can adjust your area so as to support any reasonable weight. Mr. Brunlees was the first to use this form of foundation, and by its means carried a railway across the treacherous sands of Morecambe Bay. These sands he found, by numerous experiments, possessed, at a few feet below the surface, a uniform supporting power of about five tons per square foot, if equally distributed, and this was apparently not increased if you went down to a great depth. He sank the piles by means of hydraulic pressure, thereby disturbing the sand at the feet of the piles, and allowing them to sink to the desired depth, when, the pressure being withdrawn, the sand returned to its former consistency and the piles remained stationary.

I will leave, for a moment, the question of character of foundations, and notice the pneumatic process of sinking cylinder foundations under great water pressure. This was, I believe, first introduced by Mr. Hughes in putting in the foundations for Rochester Bridge. In this case the cylinders used were, some of them, 9 feet in diameter, and others 6 feet. The joints of the cylinder were made air-tight, and a wrought iron cover securely bolted to the top. Through this cover two cast iron chambers project, $2\frac{1}{2}$ feet above the top of the cylinder, and $3\frac{3}{4}$ feet below the cover. These chambers form air locks, one for the passage of men and materials, and the other for buckets containing the stuff excavated. These air locks are furnished with cocks, communicating from the interior of the cylinder to the chamber, and from the chamber to the atmosphere. The cylinders were filled with compressed air at a sufficient pressure to withstand the head of water on the outside of them. To pass into the cylinder, the air in one of the chambers, by means of one of the cocks, is lowered to the pressure of the atmosphere, and whatever is to pass enters the chambers, when the door is closed, and the cock communicating with the inside opened, by which the pressure is gradually raised to that within the cylinder, when you can pass from the chamber into the cylinder. To come out was the same process, reversed. There was a pipe in the form of a siphon, a longer leg of which, reaching to the bottom of the pile, was subject to the pressure of the condensed air on the surface of water within, while the shorter leg, leading into the river, had the effect of relieving the cylinder from any unnecessary or irregular pressure, doing the duty of a safety valve as well as of an outlet for the continual change of air. The greatest depth of the foundations at Rochester was about 61 feet below high water, but in the construction of the foundations of the St. Louis Bridge, in America, on the same principle, part of the work was executed under a pressure of 102 feet of water. When an Act for constructing a railway under the Humber was applied for some years since, the engineer to the promoters designed an ingenious adaptation of this principle. It was proposed to build the tunnel—which was not to be anywhere more than a few feet under the bed of the river—in small sections, using an oblong chamber as a sort of diving bell, excavating the river bed, and building the section within it, and jointing it to the next section by brickwork set in cement under water as the work progresses and the air chamber is raised. The excavation would be in river silt and chalk rock.

Clay.—In carrying out works in the neighborhood of London, we have frequently to encounter what is, especially if on the side of a hill, one of the worst foundations, that of the London clay. If it is in an evil mood, it gives you but short notice. I have known an excavation look as right as possible overnight, and in the morning found the ground had surged in on us, breaking strong timbers as if they were lucifer matches. This soil, as a rule, does not slide or part piecemeal, but seems to

wait till the whole mass is of the same mind, and it then comes on you with a quiet and almost irresistible energy. There would appear to be slippery seams in it which contain or allow of the transmission of water, and the upper part will slide forward upon one of these seams, so that if you fairly disturb and set the mass in motion you can easily understand that instead of an ordinary case of angle of repose, it is a hillside with which you have to deal. The only thing is to meet it at right angles, and to disturb as small a section as possible at a time, so that any forward impulse may not be communicated to the mass, and to take care that you have strong cross walls in your basement to act as buttresses. In clay, more particularly, you must be careful to carry your foundations down to or below the ultimate drainage level, as by any subsequent draining of the subsoil it is caused to shrink and is the occasion of ugly and sometimes disastrous settlement. I have been fortunate generally, but in one case, where the money was pinched, I thought we need not carry the foundations of a portion of the building, which was only one story high, down to the depth required for the remainder, where the walls were not only lofty but very thick. The drainage caused by the larger part, which contained a basement, so affected the ground, that the outer corner of the small part with shallow foundations settled considerably. For this the just penalty of underpinning to the proper depth had to be paid. In another case a permanent water level was thought to have been left just half way up the concrete, for at any time during the building, by opening the ground anywhere in the basement, the water would in a few hours rise in the hole to that level, and never above. This looked satisfactory, but within a few months another of those useful and unpleasant metropolitan railway extensions, similar to the one referred to at the commencement, was constructed, with, of course, a drainage considerably below the level I had established. It is, however, some distance off, and the house was also thoroughly well set, and so far no damage has occurred. In this case the walls were asphalted all round up to the ground level, varying from 6 to 12 feet, and by this means the building has been kept eminently free from damp, though nothing can be wetter and colder generally than basements or foundations at that depth in the London clay. In another case, when building the eastern end of a large church on the top of a clay hill, the foundations had to be taken down about 5 feet below those of the adjacent walls, and in which a settlement had taken place some years before, passing from the ground right through the aisle, and also through the clerestory wall right up to the eaves. This looked risky, and under these circumstances I kept the concrete foundation of the new walls at as great a distance as I dare, and then threw up from them an arched underground buttress against the old walls, and built that portion of the new wall upon it. We pointed up the old settlement before commencing, and this has not opened in the least, thus removing much anxiety during the process. Adding to or making a junction with an existing building is, however, always attended with some anxiety, even when the foundations are of the best character. Not only is it well to put up all the walls of a building at the sa me time, and, if necessary, leave the completion of the interior, but it is also far cheaper; more than one building with which I have been connected having cost more from the postponement of portions and being done piecemeal. If you can do no more you ought to make an effort to have the whole of the foundations put in at the same time, so that they at least should be solid and homogeneous. Even then it will be difficult to secure a perfect bond with the teethings left out for you from the old part, as we know that all ordinary brickwork or masonry will settle a little or compress the joints. Some of our best builders, in fact, prefer, because of this, to make a junction by building into a groove or chase cut in the old walls to attempting to bond fresh work into the teeth of the old. With regard to the weight imposed on the foundations, or lower courses, of buildings of any great height or weight, it is also necessary to consider what kind of material you are using, as very recently the tower and the western wall of a church, a short distance from London have had to be underpinned on account of the lower courses crushing, the stone

used having been an inferior kind of Kentish rag. It is very seldom you come across so weak a stone, but it is well to know that it is possible to do so. No brick that would be fit to be passed as fit for any part of a good building would be liable to be crushed.

There is one kind of foundation which I have hardly touched upon—viz., timber piles with a strong timber platform on the same. This is a very common foundation in Holland, and generally, when the timber is constantly submerged, it endures for centuries. The supporting power of timber piles is a subject treated of in the office text books for both architects and engineers, and does not need comment from me. This description of foundation is the same as that which used to be employed for bridges across the Thames, but is now generally abandoned, it being considered preferable to take your foundations, cylinder or otherwise, down to the London clay. In the case of Waterloo bridge, the recent improvements, in the shape of embankments, have so increased the scour of the river that the bed is now several feet below some of the timber platforms, and measures are now being taken to strengthen and make good the foundations before they settle, like old Blackfriars. The late Mr. Page proposed a plan, I believe, for putting in cement concrete under existing foundations by means of a spoon and bag, or some such apparatus. Perhaps some member present may be able to explain it to the meeting.

M. Viollet le Duc, in his *Dictionary of Architecture*, states that the ancient Romans always founded their buildings in the most solid manner, by means of large blocks of concrete, composed of quarry rubbish, of gravel, sometimes of burnt earth, and an excellent mortar; this formed under the superstructure homogeneous basements. The Roman foundations are veritable artificial rocks, upon which one could place the most heavy buildings without any fear of rupture or settlements. During the subsequent Roman period the foundations were much neglected, and the architects of the twelfth century had seen so many instances of important edifices falling by reason of bad foundations, and of arches badly buttressed, that they paid particular attention to establish durable foundations, and to render their constructions so elastic that settlements were not to be feared. To them succeeded others, who sometimes, at the request of the ecclesiastical authorities, when means were not plentiful, attempted to make a grand or attractive show of buildings at little expense, and putting in mean and inadequate foundations, occasioned great damage to some most important edifices. Thus periods of good and bad foundations have succeeded each other like tides, or action or reaction.

In conclusion, I can only express my regret that the time at my disposal has really been so small that I feel I have not done the subject justice. I would, however, take the opportunity to urge upon everybody to whom building is entrusted its great importance, and that, though the money to be spent upon the entire work may be small, it is not in the foundations that they should be parsimonious. Let the superstructure or ornamentation be curtailed—they can be extended or attended to later on, when money may be a little more easy; but your foundations once put in, as a rule, have to remain, or, at any rate, do remain in the state in which you finish them, until after a possible catastrophe has happened.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS, 127 East 23d Street, New York—March 15th, 1882. The Society met at 8 P. M., President Ashbel Welch in the chair. The death of Gen. W. W. Wright, member of the Society in Philadelphia, March 9th, 1882, was announced. A paper by Mr. E. H. Keating, City Engineer of Halifax, was read by the Secretary. The paper described the results of the mechanical removal of incrustations from the water pipes of that city. These incrustations had become so serious as to so reduce the pressure that in many places water would not flow from the street hydrants. In some pipes the deposit was over one and one-fourth inches in thickness. Six inch pipes were found reduced to an internal diameter of three and one-fourth to three and one-half inches.

In the years 1875 and 1876 a number of miles of old three-inch pipes were cleaned by a scraper attached to iron rods and propelled by hand. The scraper had four arms or knives attached to a center, and sprung outward by a thick rubber disk. This method was not practically applicable to pipes of large diameter, but in 1880 over a mile of twelve-inch pip-

was cleaned by a scraper forced through the whole length by the head of water in the pipe. This scraper was one imported from Scotland, and its work was fairly successful. In 1881 the author of the paper constructed new scraping machines which differed from the others in having additional springs for the cutters and and the pistons. These scrapers consist of an iron rod to which are attached two pistons and two sets of cutting tools, one in front of the the other. The cutters are each made up of four strips of steel two and one half inches broad sloping backwards from the rod, and at their outer termination shaped and sharpened like the barbs of an arrow. Thus they can yield, when requisite, and the cutting diameter can be altered by moving the steel strips. The pistons are of iron, lead, and leather, to which Mr. Keating adds rubber springs. With this apparatus, and with the ordinary head in the pipes, about twelve miles of 24, 20, 15 and 12 inch pipes were cleaned at a total cost of $2\frac{8}{10}$ cents per foot. The results were remarkably satisfactory, as is shown by the fact that the average pressure on twenty-five hydrants on the wharves steadily increased from $34\frac{2}{10}$ lbs in February 1880, to $52\frac{4}{10}$ lbs in February, 1882. These were on the low service, the source of which is four miles from the city, and 200 ft. above tide. On the high service, the source being eight miles from the city, and 360 feet above tide, there is now a pressure of nineteen lbs per inch at hydrants where the water did not flow at all.

Some remarks were made on the overflow of the Mississippi River by Mr. Lyman Bridges, Member Am. Soc. C. E. The area of the water shed of that river is 1,147,000 square miles, with an annual rainfall of 80,000,000,000,000 cubic feet, and a drainage of 20,000,000,000,000 cubic feet. This is exclusive of the Red River basin. The principal levees are below the Red river. The mean annual amount of sediment passing the mouth of Red river is given by Humphrey and Abbot as 812,500,000,000 tons. The deposit of this at certain points is a source of constant danger. Levees are raised continually, but great floods, as at this time, frequently occur. The speaker suggested as a means of relief, the improvement of the old channel near the mouth of Red river, the improvement of the Atchafalaya and its parallel bayous, a connection with the Mississippi at Plaquemine, and the improvement of the outlet to Atchafalaya Bay. This would give a flood outlet one-half the length of the river from the mouth of Red river, and one-quarter the length from Plaquemine, through which 33% of the present flow could well be carried.

The necessity of complete surveys of the Mississippi was forcibly presented.

ENGINEERS' CLUB OF PHILADELPHIA.—The Secretary presented, on behalf of Mr. Thos. U. Walter, Honorary Member, a description of his experiments in 1836–7, upon the effect of extreme temperatures upon iron bands imbedded in the walls of Girard College, Philadelphia, of which he was the Architect. These bands, each, 54 ft. long, were introduced to resist the lateral pressure of the arches. Although confident that no evil could result therefrom, Mr. Walter considered the positive evidence of these experiments both satisfactory and interesting. The south vestibule wall, 5', 5" thick, subjected to the full power of the sun during summer and in winter under temporary roof, with no fires in furnaces, was selected for experiment. Self-registering thermometers, minimum for winter and maximum for summer experiment, were placed upon the bands and the whole walled in as finished work.

Smeaton's co-efficient of expansion for malleable iron, $\frac{1}{7\,6\,7}$ of length for 180°, being somewhat greater than that of other experimenters, was used. The co-efficient for brickwork, $\frac{1}{1\,8\,1\,8}$ of length for 180°, was taken from experiments by A. J. Adie, C.E., (Royal Society of Edinburgh, April 20th, 1835).

The difference occasioned by a change of 19° in temperature in a length of 54' is, therefore, less than $\frac{1}{2\,6}$", but if we consider that the exterior of the wall is subjected to the extremes of heat and cold, it will be obvious that the aggregate change of the brickwork is even greater than that of the iron.

Mr. Geo. P. Bland read a paper upon the practical strength of wrought iron columns, giving formulæ and diagram, and arguing that the factor of safety should be established with reference to the limit of elasticity.

Mr. Howard Constable exhibited a blue copy of the Kinzua Viaduct, and stated that its height will be 300' and length 2000'.

Mr. Henry G. Morris described the Hotchkiss Mechanical Boiler Cleaner which consists of a spherical cast iron vessel placed above the boiler, which it enters by a vertical flow pipe bent 90° just below low water line and opening there in funnel form; also by a return pipe carried nearly to the bottom of the boiler. The sediment, rising invariably to the surface before being deposited on the bottom or flues, is carried into the funnel, by the circulation of the water from front to rear of boiler, and reaches the spherical vessel, where it is deposited; the water returning to the boiler by natural circulation. The sediment is removed from the cleaner by opening the valve in a pipe connected with the bottom thereof, after closing the valves in the flow and return pipes.

The Secretary presented a paper by Mr. P. H. Baermann upon "What Thickness of Metal should be given to Cast Iron Pipes under Pressure?" The various formulæ are reduced to the same notation, classified and compared, and illustrated by numerous diagrams. The quality of iron, practical difficulties in casting, minimum strength required for handling, the static head, force of ram and of rapid closing of gates or hydrants and allowance for deterioration, are considered at length. A table of one fifth ultimate strengths is given. One of the main facts derived from the comparison is, that the thickness, obtained from the formulæ, give pipes of varying strength when calculated for a given head, and that the least thickness, necessary to cover imperfections in casting and for safe handling, is ample for pipes of small diameters under all ordinary heads.

ENGINEERING NOTES.

THE CHANNEL TUNNEL.—Speaking upon the subject of the works in execution for the Channel tunnel at a meeting of the South Eastern Railway Company last week, Sir E. W. Watkin said that certain sensational statements recently made in the press were false, and he was confident that Sir John Hawkshaw had never authorized the statement that he had resigned his position as consulting engineer of the company, because he (the chairman) had proposed a tunnel scheme which did not meet with his approbation. Their tunnel works had been going on for twelve or fifteen months, or longer, during which he had seen Sir John Hawkshaw over and over again, and had never heard a word of objection as to the work at all. Colonel Surtees (a director of the company) had called his attention to the fact that in 1874 it was proposed to make a shaft and sink a tunnel at St. Margaret's Bay, which was about 2½ miles from the other side of Dover Harbor, or Dover Bay. He (the chairman) referred the question in 1874 to their engineer, Mr. Brady, and the whole matter was gone into. The result was that they strongly protested against the proposal to construct a tunnel beginning at St. Margaret's Bay—first, because it practically excluded them, and secondly, because, according to the best evidence they could obtain, it was impracticable, or so doubtful and expensive that it was next door to being impracticable. After alluding to matters referring only to the shareholders, Sir E. W. Watkin observed that the way to make a tunnel cheaply, quickly, and successfully, was to find the gray chalk at its outcrop and follow it. That was what they were doing, and what, he said, those connected with the scheme eastward of Dover were not doing. The powers they obtained in 1881 enabled them to purchase the foreshore, the land at the back of it, and all the manorial rights attaching to Canterbury Cathedral. They had purchased these rights, which were now the property of the company. It was proposed to transfer a good portion of these rights, as well as the works they had made and the machinery and contracts they possessed to the Tunnel Company. They would themselves complete the works now progressing from the Shakespeare Cliff by the 31st of March, and then hand them over to the other company. The Tunnel Company had associated with them a committee to deal with the various questions arising out of this work. The legal element on the committee was represented by Sir George Bramwell, Sir Edmund Beckett, and Mr. J. F. Moulton; electrical science by Professors Siemens, Preece, and Hughes; as to hydraulic mechanical engineering they hoped to associate with them Sir Joseph Whitworth; civil engineering was represented by Sir James Falshaw, Sir F. Bramwell, C. E., and Mr. William Low, C. E.; Mr. William Spottiswoode (president of the Royal Society), and Professor Boyd Dawkins would give their advice as to geological questions; mining matters would be looked after by Mr. Charles Tayldeu Wright; military questions would be dealt with by General J. S. Brownrigg, C.B., General Sir Frederick Chapman, G.C.B., and Colonel C. F. Surtees; they would be advised as to tunnel engineering by Colonel Beaumont and Captain English, R.E. In addition to these gentlemen there would be a committee in Paris of distinguished scientific men, who had for years taken an interest in this question. The whole organization was made, and the bargain with the Tunnel Company entered into, subject to the confirmation of the proprietors.

ROADS AND ROAD MAKING.—A member of the Sheffield Highway Committee sends the following remarks on the defective asphalting on the roads and how to improve it to a local paper. He writes:—For many years past I have wished to see a machine introduced into Sheffield for properly mixing and making asphalte, and with that view I have sought after and inspected American, French, German, and foreign machines, none of which, however, complied with the conditions necessary to success, viz., economy, simplicity, cheapness, and non-liability to get out of order. Visiting at Frome, Somerset, I saw a simple machine turning out probably 20 tons per day of the best asphalte ever seen. The raw material was granite, broken into macadam of the size required for road making, and the asphalte for making footpaths was made of the small granite screenings, which was simply barrowed from a Blake's stonebreaker, and thrown into the asphalting machine at one end. In passing through the material was dried and heated by a flue under which was a fire, and on emerging therefrom a tap was turned on from a tar pipe attached, and tar was allowed to run on the hot screenings, a simple worm screw, slowly revolved, conveying and thoroughly intermixing in its passage the asphaltic material. This emptied itself out of the other end of the screw ready for use, at a mere nominal cost, a four-horse engine driving the whole. An engine-tender and two laborers only were required, one to fill and the other to empty the machine. By this process a superior quality of asphalte is obtainable. The granite from the Mendip Hills is of a peculiar carboniferous stratum, and asphalte made from the screenings possesses the property of not being slippery. I am informed neither heat, cold, nor frost affect the surface when made of this extraordinary binding material. I should like to see this cheap and splendid road material introduced and thoroughly tested on our steep inclines, say on the Glossop and Whitham Road, where the poor cab and 'bus horses can scarcely obtain a foothold these frosty and slippery mornings. An enormous saving would result from the use of this economical material; with a small staff of trained laborers and a good, competent foreman, a large surface area of the undedicated roads and footpaths within this borough could quickly be dealt with at a merely nominal cost. Horses are constantly falling on the Ranmoor and Glossop Roads, owing to the present barbarous method of covering over the coal tar macadam asphalte with a fine coating of asphalte, which is a dangerous practice, and few horses in frosty weather can safely travel thereon. Com-

ing down Glossop Road, I note our highway men are laying down asphalte on the roadway, evidently just mixed, which is a pure waste of money, as it will not stand the heavy traffic. It ought to be made and left to toughen by exposure, when it would stand four times as long as when fresh mixed. We ought to keep constantly 20,000 tons in stock ready for use whenever required. By adopting the process above described this could readily be done, and at a fourth of the present cost.

THE HOOGHLY BRIDGE.—It is announced that the long projected railway bridge over the Hooghly is to be taken in hand immediately. A site has been fixed at Chinsura, about 20 miles above Calcutta. The bridge will consist of three wrought-iron girders, each 400 feet long, and strengthened by a curved boom. The cost will be £275,000, and will be borne by the Government. The work will occupy three or four years. When finished, it will enable the East India Railway to run right into Calcutta.

ANOTHER SUBMARINE TUNNEL.—Permission has been granted to the Venetian Society of Construction to carry on the necessary preliminary works for the construction of a submarine tunnel under the Straits of Messina. According to the plan of the society, the railway line of the tunnel will branch off from that of Eboli Reggio, and, by means of a spiral tunnel, will descend to the level of the submarine line, rising to the level of the Messina Patti line in a similar manner. The approximate length of the submarine tunnel will be 2¼ miles. The rock to be traversed is extremely hard, and the thickness of the stratum left between the top of the tunnel and the bottom of the sea will be about thirty meters.

TUNNEL BETWEEN ITALY AND SICILY.—The *Bollino della Finanza, Ferrovia e Industrie* states that the Venetian Society of Public Works has asked the Government for authorization to make surveys for a project of railway communication between Sicily and the mainland, by means of a submarine tunnel under the Straits of Messina.

VARLEY'S CONSTANT BATTERY AND CONDENSER.—At the last meeting of the Society of Telegraph Engineers and of Electricians, Mr. Cromwell F. Varley, F.R.S., described a form of Daniell cell patented by him as far back as 1854 (No. 2,555). Curiously enough, this patent has been so far ignored that, according to Mr. Varley, the cells which it describes have been repatented three times, namely, by the late Sir Charles Wheatstone, by Minotti, and by Marie Davy. The cell introduced by Mr Varley to the meeting consists of a glass vessel, in the bottom of which is placed a flat cylinder or box of sheet copper, having its top perforated with holes. This is filled with crystals of sulphate of copper, and an electrode runs from it to the outside of the cell. In the mouth of the cell is suspended a conical knob of zinc, well amalgamated with mercury and having an electrode attached. The conical shape is given to serve the double purpose of allowing the hydrogen gas which is evolved at its surface to rise more freely upward than a flat plate would allow, and at the same time of allowing the metallic copper deposited on the plate to drop more freely off. A solution of one volume of sulphuric acid to one volume of water is the exciting liquid employed; and a layer of porous matter, such as burnt clay, is spread over the drilled hole in the cover of the copper box containing the crystals of sulphate of copper. These crystals dissolve in the liquid and thereby render it heavier than the purer acid solution above. The result is that it tends to remain at the bottom of the cell by its own weight, although this does not prevent diffusion of the copper salt upwards. To prevent the latter as much as possible from reaching the zinc, a siphon is occasionallly inserted in the cell to draw off a portion of the liquid below the zinc, and its place is supplied by fresh acid solution. The amalgamation of the zinc, according to Mr. Varley, insures that the latter will keep the potential due to zinc, however its surface be contaminated by copper or any other metal. Mr. Varley then described the sulphate of mercury battery, which he inserted in his 1854 patent, and which evidently anticipates the well-known Marie Davy cell. It is interesting to note, too, in connection with this patent, that the use of induction surfaces for storing-up electricity for telegraphic and electric lighting purposes is therein claimed. Mr. Varley is a far-sighted inventor, and though the induction surfaces he intends are what are known now as condensers and not "secondary batteries," such as those of Planté and Faure, it is plain that he foresaw some of the service which accumulators of the electric current would render in electric lighting. The induction surfaces were designed by him to "store up the power and so make a small battery answer the purposes of a large one, and also to act as a measure when telegraphing through long submarine cables." They were composed of sheets of tin foil separated by sheets of oiled silk, gutta-percha, or other non-conducting substance, and alternate foils were connected to opposite poles of the battery. Their use in submarine telegraphy is now universal, and they have also been employed by Jablochkoff and others in electric lighting.

RAILWAY NOTES.

RAILWAY SIGNALS.—The railway alarm signal for passengers on the Emperor Francis Joseph Railway, Austria, consists of rods under every carriage, coupled together and communicating by a system of cords and pulleys, with the steam whistle. Other cords, passing round pulleys are attached to the rods, and are led to each compartment, the ends being protected by a frame closed by a sheet of paper. This paper must be burst open before the signal can be given by the passengers.

CONTINUOUS BRAKES ON RAILWAYS.—At the annual meeting of the Amalgamated Society of Railway Servants, last October, in Man-

chester, it was decided to introduce a Bill into Parliament to compel the companies to carry out the recommendations of the Royal Commission for providing continuous brakes. This Bill is now being prepared, and Earl Delawarr has promised to take charge of it in the House of Lords. In the meantime petitions are being prepared for the signatures of the public and of railway men, urging on both Houses of Parliament the necessity of passing this measure.

AUSTRALIAN RAILWAYS AND TELEGRAPHS.—The following statistics for the 31st December, 1880, will show the number of miles of railways and electric telegraphs in the various Australian Colonies:

	Miles of railways open and in course of construction.	Miles of telegraph wires.
Victoria	1,213¼	6,019½
New South Wales	1,305½	13,188
Queensland	805	8,150
South Australia	986	6,904
Western Australia	92	1,592¾
Tasmania	172½	1,096
New Zealand	1,466	9,401
Total	6,040¼	46,351

CANADIAN RAILWAYS.—Next session the Parliament will be asked to charter a line between Fort William and Pigeon River, which separates the northeastern corner of Minnesota from Canadian territory. This line is intended to connect with a railway from Duluth to Pigeon River, in aid of which a land grant of over 20,000 acres a mile has been offered by the Minnesota Legislature. The whole distance from Duluth to Fort William by rail would be a trifle over 200 miles. The Leamington and St. Clair Railway Company has closed negotiations with the Canada Great Northern to complete and work its road from a point near Comber Station to the village of Leamington on Pigeon Bay, Lake Erie, and work has commenced. The following applications will be made to the Canadian Parliament next session:—By the Gouris and Rocky Mountain Railway Company, for an amendment to the charter to enable the company to construct its line and branches north of the 51° of north latitude. For an act to incorporate the Gaskatchewan and Peace River Railway Company to construct and work a railway from a point on the north branch of the Gaskatchewan River, between Fort a la Corne and Carleton, running northwesterly to the Peace River. By the Ottawa, Vaudreuil, and Montreal Railway Company, for an act to further extend the time for construction of the portion of the line between West Hawkesbury and Ottawa. By the Grand Trunk Railway Company, for an act to authorize the Grand Trunk Railway Company, for an act to authorize the company to purchase, lease, or amalgamate with any line of railway whose line touches or intersects any part of its line.

AT a conference of railway managers held last week at Brussels, for the organization of the Continental international service during the present year, the opening of the St. Gothard line throughout its entire length was provisionally fixed for July 1st, and arrangements were made accordingly. The opening of the great tunnel has already increased the traffic between the valleys of the Reuss and the Tessin more than fourfold. Although in former years the traffic at this season was little more than nominal, every train is now filled with passengers.

WE learn from the *Annales Industrielles* that it appears that the French Government has definitely abandoned the Achard brake, and has decided to adopt the comparatively new automatic vacuum brake due to Mr. Wenger. Our contemporary thinks it very curious that the State should recommend the air-pressure brake and adopt the vacuum. Inasmuch as several thousands of engines and vehicles have been, and are being fitted, with the Westinghouse brake, it does seem curious, that is, if our contemporary has learned his story aright, which does not seem probable.

TRAVELING on the New Zealand railways is not, according to a writer in the *Colonies and India*, all pleasure. He says:—"The speed seldom exceeds fifteen miles an hour, and so many of the lines are over steep hills, and are laid out with such an evident fondness for curves, that a high or even average speed is out of the question. Experience in this colony is hardly in favor of Government lines of railroad. There is only too much truth in the common remark that the lines are laid off with far more consideration for the convenience and property of influential landowners than regard for the levels of the land or the convenience of the majority. The grinding of the wheels upon the rails as curve after curve is described by the train is continually suggestive, not only of danger and rapid wear and tear, but of the question why, with plenty of level land about, the train turns sharp corners and mounts steep hills. Only one answer is given, viz., that a Government railroad means a political railroad. Only two classes of passengers are carried—first and second—the former paying 3d. and the latter 2d. per mile. The New Zealand railroads are now beginning to pay interest upon their cost, as well as working expenses. Notwithstanding all the blundering and extravagance in their construction, I believe that it would pay an English company well to take over these railways at their cost, and work them upon commercial principles, though I fear there is little likelihood of a colonial Government giving up so convenient an instrument of influence and power."

ORDNANCE AND NAVAL.

RECENT ADVANCES IN GUNMAKING.—A lecture on this subject was delivered on January 13, before the Portsmouth Military Association, by Col. Maitland, Superintendent of the Royal Gun Factory, Woolwich. The lecture was illustrated by sections and diagrams of English, French, and German guns,

breech mechanism, &c. Having described the metallurgy of gun construction and the action of various kinds of gunpowder, Col. Maitland said that we should be led to substitute steel for the weaker metal throughout the piece, as had been done by the Germans and the French. A very dangerous rival, however, had entered the lists against forged steel as a material for ordinance in the shape of tempered steel wire. Unfortunately, the wires had no cohesion with one another, and the great difficulty was to obtain what gunmakers called dead strength. It was of little use to make the walls strong enough if the first round blew the breech out. In the early days of wire this was what happened, and Mr. Longridge, who invented the system, was compelled to abandon it. Lately, methods had been devised for getting end strength. They were, however, in the experimental stage, and he could not say whether they would prove successful. Colonel Maitland then proceeded to describe the construction of heavy breech-loading guns. The Germans, he said, had a tube, a jacket, and hoops; the French a thick tube or body and hoops; and the English a tube, a jacket, and an overcoat, as it might be called. In the German guns the tube and hoops did nothing, as the jacket was considered sufficient. The French construction relied entirely upon the thick body, while the English method aimed at utilizing the whole section of the gun in both directions. Of course, if the other systems were strong enough, there was no particular advantage in this, and it was by no means improbable that we might eventually find it cheaper and equally good to substitute hoops for the overcoat. He next proceeded to touch upon a question which had been long hotly debated, and about which an immense quantity of matter had been spoken and written. The controversy between the breech-loading and the muzzle-loading principles had been a remarkable one, and, perhaps, the most remarkable part of it was the circumstance that, while there was now little doubt that the advocates of breech loading were right, their reasons were for the most part fallacious. It was commonly stated that a gun loaded at the breech could be more rapidly fired. This was certainly not the case, at any rate with the comparatively short guns which were made upon both systems a few years ago. It was also freely stated that with breech loaders greater protection was afforded to the gunners. This entirely depended on how the guns were mounted. If in siege works or *en barbette*, it was much easier to load a muzzle loader under cover than a breech loader. The real cause which had rendered breech loading an absolute necessity was the improvement which had been made in the powder. The slower the combustion of the powder the less difference there would be in the pressures exerted by the gas at the breech and at the muzzle, and the greater would be the advantage of lengthening the bore, and so keeping the shot under the influence of the pressure. Hence all recent improvements had tended towards larger charges of slower burning powder and increased length of bore; and it was evident that the longer the bore, the greater was the convenience of putting the charge in behind. Another advantage of the new system was the facility afforded for enlarging the powder chamber of the gun, so that a comparatively short, thick cartridge might be employed, without any definite restriction due to the size of bore. There was also another point in which breech loading had been found in the Royal Gun Factory to have a great advantage over muzzle loading as regards ballistic effect. With a shot loaded from the front it must be smaller all over than the bore, or it would not pass down to its seat. A shot thrust in behind, on the contrary, might be furnished with a band or sheath of comparatively soft metal larger than the bore. The gas then acting from the base of the projectile forced the band through the grooves, sealing the escape in a very satisfactory way, centering the projectile, and to a great extent mitigating the corroding effects of the gas. Artillerists were aware that the effect of the resistance offered by the band on the powder was to cause more complete combustion of the charge before the shot moved, and therefore to raise the velocity and the pressure. But it had escaped notice that this circumstance afforded a ready mode of regulating the consumption of the charge so as to obtain the best results. Having settled that the gun of the future was to be a breech loader, Colonel Maitland described various methods which had been adopted for closing the breech. It was, he remarked, difficult to compare the excellence of the different systems, as much depended on the care of the gunners and the niceties of manufacture. As regarded durability there was probably no great difference. As to the general principle of gun construction it should not be overloooked that the motive power was powder, and the purpose to be accomplished a hole in an armor plate, perhaps a breach in a concealed escarp, or destructive effect on troops. No single gun was capable of realizing more than one result in the highest state of excellency. For armor piercing a long pointed bolt was required. It must strike with very great velocity, and be propelled by a very large charge of powder. Hence, an armor-piercing gun should have a large chamber, and a comparatively small bore of great length. For breaching fortifications, on the other hand, it was clear that for a shell to drop at an angle of 15 deg. to 20 deg. at the end of a moderate range, the velocity at starting must be low. Hence, for pieces intended for breaching, no enlarged powder chamber was wanted. What was required was a large bore, but without any great length. For use against troops it was necessary in order to obtain the best results from shrapnel, that a considerable remaining velocity was needed. The gun must consequently have a large powder charge, while as the shell had to hold as many bullets as possible the bore should be large enough to take a shortish projectile of the given weight; the shrapnel gun would thus be intermediate between the armor-piercing and the shell gun.

In conclusion, Colonel Maitland remarked that there were certain axioms which were known from experience. The length of the powder chamber should not be more than three and a half times the diameter, because with longer charges the inflamed powder-gas was apt to acquire rapid motion and to set up violent local pressures. The strength of a heavy gun should not be less than about four times the strain expected. Though there were several opinions as to the best weight of shot for armor piercing in proportion to diameter, yet there was a growing tendency towards increased weight. He believed that the competition among scientific artillerists was now more keen than it had ever been, and if England was to keep her place in the van of progress she must afford every facility for experiment. She must neither spare expense in the Royal establishments nor discourage private enterprise, to which so much was owing.

COMMUNICATION WITH SHIPWRECLED VESSELS.—Some interesting gun experiments are being made for communicating with vessels in distress. The gun selected for the purpose is 2 feet long, with 2½-inch bore, and shoots a line 200 yds. with 2 oz. of gunpowder. The shot consists of a canister, which, on being discharged from the gun, leaves a line streaming behind it. The distance the line to be projected can be increased by increasing the size of the gun. Hitherto, the usual mode of communicating with shipwrecked vessels from the shore has been by means of rockets. Science, however, suggests that more effectual means may probably be arrived at by diligent research, and with this object the present gun experiments are being carried out.

STEEL-FACED ARMOR-PLATE TRIALS.—The first armor plate for the protection of the double screw barbette ship *Collingwood*, 9,150 tons displacement, now building at Pembroke, was tested on board the *Nettle*, at Portsmouth, on January 6. It is intended to protect the sides of the *Collingwood* by side armor of the great solid thickness of 18 inches, of which the steel face is 6 inches and the iron backing 12 inches. Each plate will measure 8 feet in height and about 12 feet in length, the lowermost plates of the series tapering from one-half of their length to 8 inches at the lower edge below the water line. The plate tested, as a sample plate of from 400 too 500 tons of similar plates, is intended for the citadel, which will be protected by plates of the same weight, but rolled from 18 inches to 11 inches in thickness, of which 3¾ are steel and 7¼ iron. It was manufactured by Messrs. Charles Cammell and Company, Sheffield, according to Wilson's patent, measured 8 feet in height by 6 feet in breadth, and weighed 9 tons 16 cwt. The remarkably satisfactory manner in which it passed through the crucial ordeal by fire, demonstrated the great perfection to which the manufacturers have attained. Three shots were fired at it at 30 feet range with the 12-ton 9-inch muzzle-loading rifle gun, the charge being 56 lbs., the weight of projectile 250 lbs. and the initial velocity 1,450 feet per second. The first round struck 2 feet 6 inches from the right edge and 4 feet 6 inches from the lower edge. The indent measured 10 inches by 9½ inches. The impact produced four very fine cracks, the first being circumferential to the indent, and none of them of any consequence. The projectile was knocked out of the plate by the blow of the second shot, when it was ascertained that the penetration had not proceeded beyond 4.5 inch. The next round struck the target 2 feet from the right and 2 6½ inches from the lower edge, and making an indent 10½ inches by 10 inches in diameter. The result of the blow was to produce three more hair cracks and to open out No. 3 crack slightly. On removing the wedge, however, from the frame, it was found to extend no further than just through the steel face. As the head of the projectile remained embedded in the plate, the depth of the penetration could not be measured. The third and final round struck 2 feet 1 inch from the left and 3 feet 6 inches from the lower edge. The diameter of the indent was 9 inches by 10½ inches, and the penetration 4.7 inch. No fresh cracks were made by this shot, but it caused Nos. 2 and 5, produced by the previous rounds, to extend to the edge of the plate. The whole of the projectiles were broken up into unusually small pieces. This plate is the most satisfactory that has yet been operated upon. The penetration was comparatively small, and, while the cracks were few and unimportant, none of them piercing the backing, there was no buckling of the plate observable, which is also quite exceptional.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

MONTHLY WEATHER REVIEW FOR JANUARY. Washington: Government Printing Office.

SCIENTIFIC PROCEEDINGS OF THE OHIO MECHANICS' INSTITUTE. Cincinnati: Published by the Institute.

LETTERS FROM LEADING ENGINEERS AND NAVAL ARCHITECTS AS TO THE PRACTICABILITY OF CONSTRUCTING AND OPERATING A SHIP RAILWAY. St. Louis; G. I. Jones & Co.

PROCEEDINGS OF THE ENGINEERS' CLUB OF PHILADELPHIA. Vol. 2, No. 3.

AERIAL NAVIGATION. By William Pole, F. R. S. Published by Institution of Civil Engineers.

ABSTRACT OF PROCEEDINGS OF THE SOCIETY OF ARTS FOR 18TH AND 19TH YEARS. Massachusetts Institute of Technology.

HISTORY OF THE WATER SUPPLY OF THE WORLD. By THOMAS J. BELL. Cincinatti: Peter G. Thompson.

DE INDISCHE GIDS. January, 1882. Amsterdam: J. H. DeBussy.

GENERAL LIBRARY University of MICHIGAN

THE BRITISH NAVY; ITS STRENGTH, RESOURCES AND ADMINISTRATION. By Sir Thomas Brassey, K.C.B., M.P., M.A. Vol. 1. Part I., Shipbuilding for the purposes of war. London: Longmans, Green & Co. Price $5 00.

The present volume, although one of a series of six, appears in the market to be sold as a separate work, as it contains that portion which alone will be of popular interest. The second volume will treat of armor, armaments, torpedoes, etc. The third is a collection of papers giving the views of different authorities on the shipbuilding policy of Great Britain. The fourth and fifth volumes contain parliamentary speeches, and essays contributed to the Reviews. The sixth volume is a reprint of a former work on merchant seamen.

The contents of the first volume are—Historical Sketch, Naval Requirements in War, Classification of Ships of War, Earliest Ironclads, Progress of Armored Ship building in France, from 1861 to 1873, Early Armored Construction in England, Converted Ships, Sir E. J. Reed's system; Austrian, German, Italian, Turkish, Russian and Spanish Iron clads; Monitors and Earlier Armored Vessels for Coast Service. Vessels of More Recent Type: Armored Cruisers, Bow Battery-Ships, Central Battery-Ships, Masted Turret-Ships, Mastless Turret-Ships, Mastless Barbette-Ships, Unarmored Cruisers and Special Vessels of the Chief Naval Powers.

The details of construction of the principal war vessels are exhibited in a series of folding plates, fourteen in number, in which coloring is used to aid in distinguishing parts exhibited in sections. Full page wood cuts of twenty-five of the celebrated ships and lesser cuts to the number of 310 illustrate the text.

Much patient, skillful labor has been expended in the preparation of this handsome volume. The author's own view of the character and importance of the work is fairly expressed in the following paragraph from the preface:

"Days and nights which should have been given to rest from other labors, to literary culture, and the kindly offices of friendship have been devoted to the present work, and no small portion of it has been prepared under conditions far from favorable, in a scanty cabin, six feet square, rocked on the uneasy billows of the open ocean. I could not have persevered if I had not felt it my duty to bring to completion the enterprise on which I had embarked. The sea has been a passion with me from my boyhood; but it has only been in later life and by a chain of circumstances apparently fortuitous, that the disappointed memories of long vacations spent afloat, which should have been occupied with methodical study, have been partially soothed by the hope, in which I try to indulge, that my nautical experiences have been applied, not altogether in vain, to the service of my country."

LEÇONS SUR L'ELECTRICITE ET LE MAGNETISME.—Par E. Maseart et J. Joubert. Vol. I. Paris: G. Masson.

This is a theoretical treatise and is intended to explain to the French student the views of Faraday and Clark-Maxwell.

Seven hundred and twenty royal octavo pages, including 127 figures, are devoted to general phenomena and theories. Vol. II. is not yet published.

THE HORSE IN MOTION, AS SHOWN BY INSTANTANEOUS PHOTOGRAPHY.—By J. D. B. Stillman, A.M., M.D. Boston: James R. Osgood & Co. Price $10.00.

A large and elegant book is devoted to what might seem to be an unimportant subject; but a brief glance at the beautiful illustrations convinces at once that the subject justifies the space assigned to it, and the handsome form in which it is presented.

No better starting point for the treatise on animal mechanics could be conceived than the instantaneous views which illustrate so abundantly this volume.

GEOLOGICAL SURVEY OF NEW JERSEY.—Annual Report of the State Geologist for the year 1881. Trenton: John L. Murphy.

The Report is accompanied by a beautiful colored geological map of the State. The text covers something more than one hundred octavo pages, and treats of the following subjects:

The United States Coast and Geodetic Survey of New Jersey, Topographical Surveys, Geological Notes, Ores of Iron and other Metals, Quarry Stones and Statistics, Clays, Bricks, and Pottery, Drainage, Water Supply, Statistics, Publications, Expenses, Persons Employed, Work to be Done, Plan for the Coming year, Appendix, Climate, and Meteorology.

The State Geologist is Prof. George H. Cook; Assistant Geologist, Prof. John C. Smock.

A MANUAL OF SUGAR ANALYSIS, INCLUDING THE APPLICATIONS IN GENERAL OF ANALYTICAL METHODS TO THE SUGAR INDUSTRY. WITH AN INTRODUCTION ON THE CHEMISTRY OF CANE SUGAR, DEXTROSE, LEVULOSE, AND MILK SUGAR. By J. H. TUCKER, PH.D. New York: Van Nostrand. Price, $3.50.

It is a remarkable fact that extensive as are the interests connected with sugar, and frequent, or rather constant, as are the applications of chemical science which they require, there existed hitherto no work in the English language dealing systematically with this branch of chemical analysis. Our apathy on the subject is the more remarkable when it is considered that we are far greater sugar consumers than any other European country, and that the British Empire alone is probably able to supply more sugar than any other State in the world. France, Germany and Austria, on the other hand, have been as active as we have been remiss; and thanks to their energy and perseverance, beet-root sugar, one of the weapons devised against us by the first Napoleon, has become a formidable rival to the true cane sugar. We say "true," because, although analysis has hitherto not succeeded in showing any distinction between the saccharose of the

cane and that of the beet, many persons can distinguish the two by the taste. Bees, we understand, where they have the choice, will crowd to cane sugar and leave beet sugar untouched, and a suspicion is gradually gaining ground that the physiological action of these two sugars is not identical.

The author sets out with a summary of the chemistry of the sugars as a class, and then gives a more especial description of saccharose, to which he devotes an entire chapter on dextrose, levulose, and invert sugar and of lactose. We venture here to propound a question: Starch, it is said, in any of its forms, when taken as food, cannot be digested until converted into sugar. Why, then, are the physiological actions of starch and of sugar so different?

Dr. Tucker proceeds in the next chapter to the determination of the specific gravity of the solutions of sugars. It is somewhat remarkable that he omits all mention of Twaddle's hydrometer whilst speaking at length of the very inferior instrument of Baume, which has been so justly denounced by Professor Bolley. In the chapter on the determination of cane sugar by optical methods, he describes the saccharimeters of Mitscherlich, Soleil-Duboscq, and Soleil-Ventzke, Wild's polaristrobometer, the "shadow saccharimeters" of Duboscq and Schmidt and Hanesch, and the method of Clerget, with the accompanying table. He states in a note that this process (Clerget's) is entirely inapplicable when any optically active body is present besides cane sugar or invert sugar, and also if the invert sugar itself exists in an inactive condition as regards polarized light. To this criticism we cannot subscribe.

The chemical methods for the determination of cane sugar next follow. The process of Peligot is not regarded as very accurate; extraction by alcohol gives good results where the quantities to be dealt with are but small. The fermentation process is justly pronounced "open to many objections." The processes for the analysis of raw sugars and sirups are the best known, and they are ably and clearly described. Still, we fear that they will, under very possible circumstances prove unsatisfactory in practice. Further research is needed before the analyst can find himself in possession of methods suitable for every possible mixture of a class of bodies so nearly related in composition and not marked by any very striking reactions. An important section is devoted to the detection of two modern and increasing frauds—the addition of dextrin, and of starch, or corn sugar, to raw or refined sugars. Dextrin is added to raw sugars to give them a higher polarization: 0.40 per cent of dextrin raises the optical standard 1 per cent. For its qualitative detection the author adds in a concentrated solution of the sample alcohol at 95 per cent. A white, thread-like coagulum shows the presence of the adulteration. Unfortunately, calcium sulphate gives a similar result. Iodised potassium iodide gives a vinous red, or violet color, with some samples of dextrine, but not with all.

Starch or corn sugar is now, at least in America, added in large proportions to sugar, sirups, preserved fruits, &c., and goes under the euphemistic name of "new process sugar." Its price is unfortunately very low—about 3d. per lb.—so as to leave a large margin for the unscrupulous. We may here remark that, according to the experiments of Professor Nessler, this substance is decidedly unwholesome. The author admits that there is no accurate method for the quantitative determination of this adulterant. Its presence may be qualitatively detected by attending to the three following points: Sugars mixed with corn glucose on solution in water leave white particles of the glucose undissolved. If a sugar adulterated in this manner is examined with the polariscope, the reading does not remain constant, but gradually becomes less. A refined sugar mixed with starch sugar will show too high a percentage by the saccharimeter, so that the results appear more than 100 per cent. Two chapters are devoted to animal charcoal. Amongst the synonyms of this substance the author omits the name "spodium," which it commonly bears in Germany. The following passage deserves especial notice:—"There has been a method proposed in France for the estimation of cane sugar in raw sugars, known as the *four-fifths method*, and is, I believe, used to some extent in commercial analysis. It consists in taking four-fifths of the ash as the number expressing organic matter, not sugar. The sum of this—the ash, water and glucose—subtracted from 100 represents the cane sugar. The method is not worth mentioning, except as a curious example of the aberations to which the human mind is subject." This process outdoes even the so-called "commercial method" of determining phosphoric acid in coprolites, superphosphates, &c., viz, by adding ammonia and accounting for the entire precipitate as tricalcic phosphate.

Dr. Tucker's work is well illustrated, and in case of some of the less common instruments described and figured, the adress of the maker is given in a foot note. The getting-up of the book is excellent, with, perhaps, the exception of the index and of certain tables, which are in an uncomfortably small type. The work decidedly supplies a want which must long have been felt, and it places in the hands of the profession information which must otherwise be sought up, at great outlay of time, in the foreign journals.—*Chemical News.*

MISCELLANEOUS.

DYNAMO-ELECTRIC machines are now being used in porcelain manufacture. The paste used for porcelain often contains ferruginous particles, which give the baked articles a color, or a minutely spotted appearance, where a pure white may have been desired. In this way ceramic products may lose as much as 50 per cent. of their value. The attempt hitherto made to remove those traces of iron with magnets have met with poor success. Recently, however, at two important French works, the Faïencere of Creil, and the estab-

lishment of MM. Pilivuyt & Co., of Mehun-sur-Yevre, it was decided to set up powerful apparatus in which the electricity, instead of being supplied from batteries, was obtained by means of a small Gramme machine driven by a steam engine. The arrangement, which is said to work well, comprises a strong horizontal electro-magnet, with the poles very near each other, and between them a thin box. The paste, very liquid, enters the upper part of this box and is deflected towards the polar sides by a bent piece of zinc. As it flows down these sides the iron corpuscles are caught on them by the magnetic force. The apparatus is cleaned twice a day, by means of a jet of water, the magnet being demagnetized for the time. About 1 gramme of iron particles is stopped in the passage of 12 kilos. of paste, and 500 to 600 kilos. of paste may be passed through one apparatus in a day.

THERE is considerable disparity in engineers' opinions respecting crowd weights, or the actual weight which should be allowed for as the crowd load of a bridge. The following is from *Calvert's Mechanics' Almanac:* Mr. E. A. Cowper states that he had placed a number of men together, and they weighed 140 lbs. to the square foot. Mr. Parsey is of opinion that, upon an average, men, when put together closely, would weigh at least 112 lbs. per square foot, but in ordinary crowds of people 80 lbs. might be taken as sufficient. While Englishmen would weigh about 150 lbs., a Belgian would weigh 140 lbs., and a Frenchman 136 lbs. Mr. F. Young, at a meeting of the Society of Engineers, said 80 lbs. per square foot was quite safe in practice. Mr. George Gordon Page, in a paper on the construction of Chelsea Suspension Bridge, says for troops on march, 21in. in rank and 30in. in pace are allowed, giving 4.37 superficial feet per man, which, at 11 stone, would be 35¼ lbs per square foot. The load taken in the calculation for the Menai Bridge was 43 lbs. per superficial foot. An experiment was made by the engineer of the Chelsea Bridge, by packing picked men on a weighbridge, with a result of 84 lbs. per superficial foot, but it is not likely that such a crowd could accumulate on any bridge. It may here, perhaps, be useful to add that a cavalry horse weighs about 11 cwt.; a strong cart horse, about 14 cwt.; and a riding horse, about 8 cwt. The weight of horses in the United States ranges from 800 lbs. to 1200 lbs. The average weight of 2000 men and women, weighed at Boston, 1864, was—men, 141½ lbs.; women, 124½ lbs. The average weight of an elephant is 60 cwt.; a camel, 10½ cwt; large ox, 10 cwt.; small ox, 6 cwt.; cow, 6½ cwt; heifer, 3½ cwt.; pig, 1½ cwt.; and sheep, 60 lbs. to 90 lbs.

THE committee announce that the new inventions not patented, exhibited at the Smoke Abatement Exhibition, are protected by special provisions of the Board of Trade. They also state that inventors having apparatus of which models cannot be prepared in time for exhibition may send in drawings of the same.

ACTION OF LIGHT ON SILVER RESISTANCES.—The researches of Professor Bell, M. Mercadier, and others have shown that selenium is not the only substance which is affected in its electric resistance by light; and the recent experiments of M. Bœrnstein would appear to demonstrate that silver should also be added to the category. He took two plates of glass chemically covered with a thin coat of silver. The ends of the plates were electrotyped with copper and used to connect the two other branches of a Wheatstone "bridge." When a balance had been obtained one of the films of silver was lit by the ray from a spirit lamp colored with sodium. The influence of the light was to increase the resistance of the silver, and that the maximum resistance was only attained at the end of a certain time. It would be more satisfactory to feel sure that the increase of resistance was not due to heating by the rays.

A NEW MAGNETO-ELECTRIC EXPLODER.—M. Marcel Deprez, the eminent French electrician, has constructed a new magneto-electric machine for exploding mines and torpedoes which possesses several points of interest. Instead of passing the instantaneous current induced in the coiled armature suddenly snatched from the poles of the magnet, directly through the wires to the fuse in the mine, he passes it through the primary circuit of an induction coil, and the secondary spark from this coil is sent along the wires to explode the mine. This change necessitates some modification in the exploder as ordinarily made. For instance, the wire of the armature coil ought to be thick so as to give small resistance, and the induced current due to the withdrawal of the armature should be broken when at its maximum strength, in order that the rupture may induce a maximum current in the secondary circuit of the induction coil. M. Deprez also found that ordinarily the armatures of exploders contained too much iron, and he has therefore reduced this feature. In the new exploder of M. Deprez, the armature consists of a coil of stout wire wound on a core of sheet iron which is carried by two crank levers mounted on the same axle. By striking a small pedal attached to the other arms of these levers the armature is suddenly jerked away from the poles of the horseshoe permanent magnet it rests against, and the spark generated flows into the primary of the induction coil. The interrupter of the latter is to be adjusted so as to give the longest spark from the secondary.

ON CEMENT.—Some useful results obtained by German experimenters on the behavior of cement under different conditions are given in the current volume of *Dingler's Polytechniches Journal*, p. 1088. According to Herr Schumann, all cements, if allowed to harden in water, increase in volume, the largest increase taking place during the first period of setting. The increase is larger with newly-prepared cement, smaller with finely-ground cement. The addition of gypsum also increases it, while the admixture of sand di-

minishes it. Building stones were likewise found by Schumann to expand in water, and contract again on being dried in air. The greater the porosity of the stone the smaller is the increase in volume. These changes are, however, in his opinion, too slight to interfere with present practice in building operations. With regard to the behavior of concrete under heat, Herr Feege finds that it can be exposed to a temperature of 130 deg. to 150 deg. Cent. without injuring its supporting strength. At higher temperatures, however, it loses firmness and becomes brittle. An important fact bearing on the preparation of mortar was elicited by Schumann's experiments. He found that that all cements, whether used as fine or coarse powder, or burnt slightly or strongly, give the same yield of mortar, and therefore recommends weighing the quantity of cement instead of measuring it as is usually the case. We should add that Herr Delbruck objects to prepare concrete under water, and holds that all excavations should be kept as dry as possible during the actual process of concreting. Herren Busing and Dyckeshoff, on the other hand, strongly recommend concreting in water, and cite many large undertakings in which it has been successfully effected.

SHIPBUILDING.—The tonnage statements of the vessels that have been launched last year show the marked progress that has been made in shipbuilding at many of the chief ports, and the great competition that has been known amongst some of the chief shipbuilders. The first place is taken by the Palmer Shipbuilding Company, of Jarrow, which has launched over 50,000 tons of shipping. But the second position on this occasion seems to have passed to Barrow-in-Furness by a few tons; the third place in the rank of producing firms being taken by Messrs. W. Gray & Co., of West Hartlepool. The largeness of the contributions to the total are remarkable, and the extent to which the northeastern district—from Blyth to Whitby—has launched vessels, is also very notable. But it will be probably found when the figures for that district are analyzed, that there has been in the past year a reduction in the tonnage of steel steamers built, as compared with the previous year. The demand for iron vessels has been so large that firms that had previously entered into the building of steel vessels have laid it aside. Another fact that strikes the inquirer is, that the vessels built are now such as consume a larger quantity of iron than formerly—many parts of the vessels that were built of wood down to a short time ago, have now been generally made of iron. There is a distinct tendency, moreover, to increase the average tonnage of the vessels built. But on all points the year 1882 opens with prospects for the shipbuilders that are brighter than were those of its predecessor. There is on all hands fullness of work, and in some instances orders that will last through the whole of the year, so that, failing any unexpected check the tonnage built in 1882 should be above that of the past year.

THE CALORIC OF CARBON.—Mr. Jacob Reese, in a paper read before the Engineers' Society of Western Pennsylvania, remarks:—"The great want of the present age is a process by which the static caloric of carbon may be set free by non-luminous combustion, or, in other words, a process by which coal or oil may be oxidized at a low degree within an insulated vessel." This cannot be too prominently brought forward. "If it can be accomplished," as Mr. Reese says, "we would be able to produce from twelve to fifteen million foot-pounds of electricity from one pound of petroleum, or from ten to twelve million foot-pounds of energy from one pound of good coal."

THE NEW ATLANTIC CABLE.—The steamship *Faraday* left the works of Messrs. Siemens Brothers at Charlton on January 10, with the last portion of the New Atlantic telegraph table, which is to be forthwith completed for the American firm of Gould & Co. The cable is of special kind and remarkable for its strength, the shore end weighing 18 tons per mile and the deep sea and intermediate sections being to correspond. More than 1,100 miles have been taken on board at the rate of 50 miles per day, and the cable, when completed, will be 3,000 miles in length. The *Faraday* has made three voyages on the same work, leaving the end of the cable on each occasion buoyed in the Atlantic, where it has endured the storms of the past year without the slightest injury.

EXTENSIVE USE OF ELECTRIC LIGHT ON THE CONTINENT.—A scheme is on foot, says *Nature*, having been approved by the Municipal Council of Paris, for lighting with electricity the quarters of the Prefecture of the Seine, in the Tuileries. It is the work of M. Cernesson, and comprises lighting the Salle des Séances with eighty Swan lamps (in place of eighty Carcel lamps), and six Siemens' arc lamps; lighting the library with forty-eight Maxim incandescent lamps (on the present lusters); another room with twenty-four Lane-Fox incandescent lamps; another with twenty Swan lamps; the Salle des Pas Perdus with two Werdermann lamps; a lobby with two Siemens, lamps, and a staircase with four Brush lamps. The whole will require an outlay of 75,000 fr. The horse power necessary is 44, and while the idea of obtaining this from the Seine has been considered, it has been decided to set up a gas engine in the Court of the Tuileries. A portion of the motor force is to be employed for electric hoists, for driving ventilators, and other uses. The Paris Lyon-Méditerranée Company have illuminated their Paris terminus with fifty-four electric lamps on Lontin's system, and that of Marseilles with seventeen of the same lamps, a number which is to be increased by eighteen. The French Northern Company has tried, with success, the use of the electric light in the front of locomotives. The Turin Municipality have decided on trying the electric light for the Theater Royal.